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HERITABLE VARIATION IN NODULATION OF *CENTROSEMA PUBESCENS* BENTH.

By G. D. Bowen, B.Sc.* and Margaret M. Kennedy, B.Sc.†

SUMMARY

Field and glasshouse observations revealed extreme variation in nodulation and plant growth within several commercial seed lots of *Centrosema pubescens* Benth. inoculated with each of many Rhizobium strains.

Inoculation of vegetative propagations of plant selections and of seed from these showed that commercial seed contained stable sparsely nodulating and profusely nodulating lines.

Following inoculation with most Rhizobium strains, plants of the sparsely nodulating lines were greatly inferior to others in nodulation and yield in a nitrogen-deficient substrate. However, certain Rhizobium strains were found to nodulate these lines satisfactorily, good plant growth ensuing.

Profusely nodulating lines produced a greater number of nodules than average plants in commercial seed lots, but total nodule weight per plant and plant weight were unaltered by the profuse nodulation.

I. INTRODUCTION

The legume *Centrosema pubescens* Benth. has long been used extensively in tropical and subtropical regions as a green manure and cover crop (Whyte, Nilsson-Leissner, and Trumble 1953) and more recently in Queensland as a legume component of pastures. It has been shown previously (Bowen 1959*b*) that the number of nodules formed, the total nodule weight per plant, and plant yield of this legume vary with the Rhizobium strain used for inoculation. However, during nodulation studies (Bowen 1959*a*, 1959*b*) considerable variation of number and position of nodules, and of plant growth, was observed between adjacent plants growing in a uniform environment and inoculated with pure cultures of Rhizobium. This study investigates the hereditary nature of this variation.

II. MATERIALS AND METHODS

Seed.—Initial observations and plant selections were made on plants grown from *C. pubescens* seed of Malayan origin commercially available in Queensland.

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Surface Sterilization of Seed and Plant Material.—Seed was surface-sterilized with either 0·1 per cent. mercuric chloride for 5 min or equal parts of ethyl alcohol and 20 volume hydrogen peroxide for 10 min. Plant material used for vegetative propagation was lightly surface-sterilized by wiping thoroughly with cotton wool soaked with 7 per cent. calcium hypochlorite filtrate. All surface sterilization was followed by washing the material in sterile water.

Vegetative Propagation.—In some instances surface-sterilized stolons were rooted directly in the testing units; in other cases the stolons were rooted in sterile sand before severance from the main plant and transfer to the testing units.

Inoculation and Growth of Plants.—Plants were grown in a closed glasshouse in sterile washed river sand in testing units of a modified Leonard type (Leonard 1943), using a plant nutrient solution with nitrogen omitted (C. S. Andrew, personal communication). The test organism was introduced by inoculation of the seed with a high concentration of rhizobia or by application of 1 ml of a suspension of the rhizobia to the base of each seedling. Details of the performances of strains QA523, QA549 and QA837 in glasshouse studies have been published previously (Bowen 1959*b*).

III. RESULTS

(a) Variation in Nodule Numbers

Considerable variation in numbers of nodules on plants grown from commercial seed was observed both in sand culture in the glasshouse (Figure 1) and in the field (Figure 2). These large variations were recorded in the field with several Rhizobium strains and with commercial seed from three Queensland and five overseas sources.

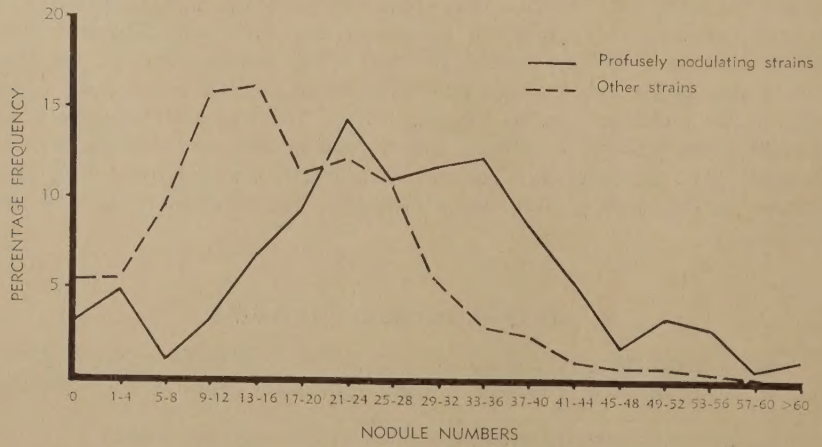

Fig. 1.—Distribution of nodule numbers per plant of *Centrosema pubescens*. Commercial seed inoculated in the glasshouse with profusely nodulating and poorly nodulating Rhizobium strains (Bowen 1959*b*). Data obtained from approximately 200 plants in each category.

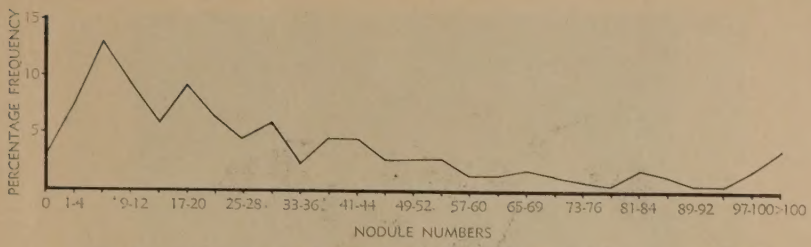

Fig. 2.—Distribution of nodule numbers per plant of *Centrosema pubescens*. Inoculated commercial seed planted in wallum-heath soil, February 1957. Plants 14 weeks old when examined.

In each case some plants were devoid of nodules or only sparsely nodulated and others were profusely nodulated compared with the normal nodule number. In both the glasshouse and the field, 3-5 per cent. of the plants did not form nodules.

The distribution of nodule numbers shown in Figure 1 renders the definition of sparse nodulation somewhat arbitary, but by taking less than one-third of the mean number of nodules per plant as a measure of sparse nodulation, 10-12 per cent. of plants in glasshouse sand culture and 30 per cent. of those in the field would be placed in this category. The higher proportion of apparently sparse nodulation in the field may result from the differences in growth conditions between glasshouse and field and the experimental errors inherent in field trials. In some soils where growing conditions tended to be adverse to nodulation, the proportion of poorly nodulated plants was higher than the above.

A tendency was observed in field studies for plants with sparsely nodulated main roots to also have sparsely nodulated stoloniferous roots.

Under conditions of nitrogen deficiency sparsely nodulated plants were yellow and noticeably smaller than adjacent well-nodulated plants (Figure 3). Some of the sparsely nodulating plants were also nodulated late (Figure 4).

(b) Nodulation of Vegetatively Propagated Plant Selections

Two series of vegetative propagations from field selections of profusely nodulated and non-nodulated plants were inoculated with Rhizobium strain QA549. This strain was a proven good strain and was available for commercial inoculation of *C. pubescens*. Nodule counts after eight weeks (Table 1) indicated that the clones maintained the selected character. However, since some plants of the clones from non-nodulated parent material produced nodules—these always being few in number—the "non-nodulating" character is more accurately described as sparsely nodulating.

Fig. 3.—Sparsely nodulating plant (yellow) of *Centrosema pubescens* growing among normal plants (green and vigorous).

TABLE 1

NODULATION OF VEGETATIVELY PROPAGATED SELECTIONS

Experiment No.	Non-nodulating Selections			Profusely Nodulating Selections		
	No. of Plants	No. of Nodulated Plants	Nodule Numbers/ Plant	No. of Plants	No. of Nodulated Plants	Nodule Numbers/ Plant
1 ..	10	6	0·6	17	17	16·3
2 ..	18	14	4·3	12	12	14·1

(c) Nodulation of Seedlings from Plant Selections

Seed was produced from five profusely nodulating and six sparsely nodulating field selections (subsequently referred to as P and S selections respectively). The seed and commercial seed were surface-sterilized and inoculated with Rhizobium strains QA523a and QA549. The results shown in Table 2 and Figures 5 and 6 were obtained after nine weeks and are derived from four replications of six plants per testing unit.

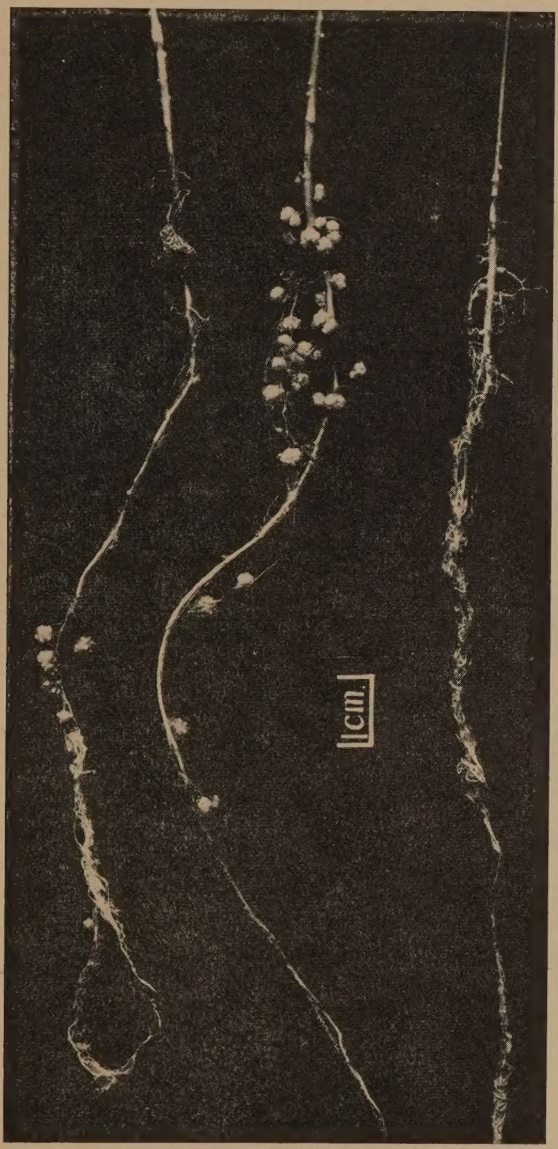

Fig. 4.—Roots of glasshouse plants all inoculated with Rhizobium Strain QA549 and growing in the same pot. Left, sparse and late nodulation. Centre, normal plant. Right, nodules absent.

TABLE 2

NODULATION AND GROWTH OF SEEDLINGS FROM PLANT SELECTIONS

Plant Selection	Mean No. of Nodules/Plant		Mean Oven-dry Weight of Nodules/Plant (mg)		Mean Oven-dry Weight of Plant Top (mg)	
	Inoculum		Inoculum		Inoculum	
	QA523a	QA549	QA523a	QA549	QA523a	QA549
(*a*) Sparsely nodulating*						
1	2·2	3·3	1·5	4·2	68·5	160·6
2	4·5	4·0	4·1	3·1	102	90·3
3	0·1	0·7	0·2	0·8	40	42
4	0·4	0·3	1·5	0·7	59·7	47
5	0·04	0·	0·2	0·	57	46
6	1·3	3·3	3·1	5·6	76	98·5
(*b*) Commercial seed						
7	6·5	9·5	14·2	16·2	240·5	258
(*c*) Profusely nodulating						
8	16·9	17·1	18·0	18·9	233	230
9	17·1	13·6	16·8	11·5	203	163
10	15·9	11·1	18·9	15·0	237	190
11	11·8	17·3	20·0	19·5	256	248
12	13·4	12·3	21·2	10·9	266	177
	8, 9, 10, 11, 12>>7 8>12		No significant differences		No significant differences	
Uninoculated seed ..	0		0		78	

* Because of the obviously highly significant differences between poorly nodulating selections and the rest, data from the former were not included in the statistical analysis.

The large differences between seedlings from S selections and other seed lots strikingly confirm that the amount of successful rhizobial infection (nodule formation) is determined by heritable characters of the plant, and that there exist in commercial seed separate stable lines with differences in nodulation potential. The greater nodule number of P lines than of normal plants from commercial seed was accompanied by a reduction in mean nodule size. This resulted in total nodule weight and plant response being the same in both cases. Plants of Selection 8 produced more nodules than those of Selection 12.

(d) Nodulation by Selected Rhizobium Strains

In earlier studies (Bowen 1959*b*), a few Rhizobium strains appeared to nodulate all plants. One of these was QA837. In some instances S selections nodulated profusely over a short period after some months in the glasshouse. Nodules from such material were used for isolation of strains QA869 and QA870. The Rhizobium strains QA549, QA837, QA869 and QA870 were inoculated to S lines, P lines and unselected material. In two of the five replicates (each with four plants) surface-sterilized seed was inoculated before planting, and in the remaining three seedling inoculation was carried out.

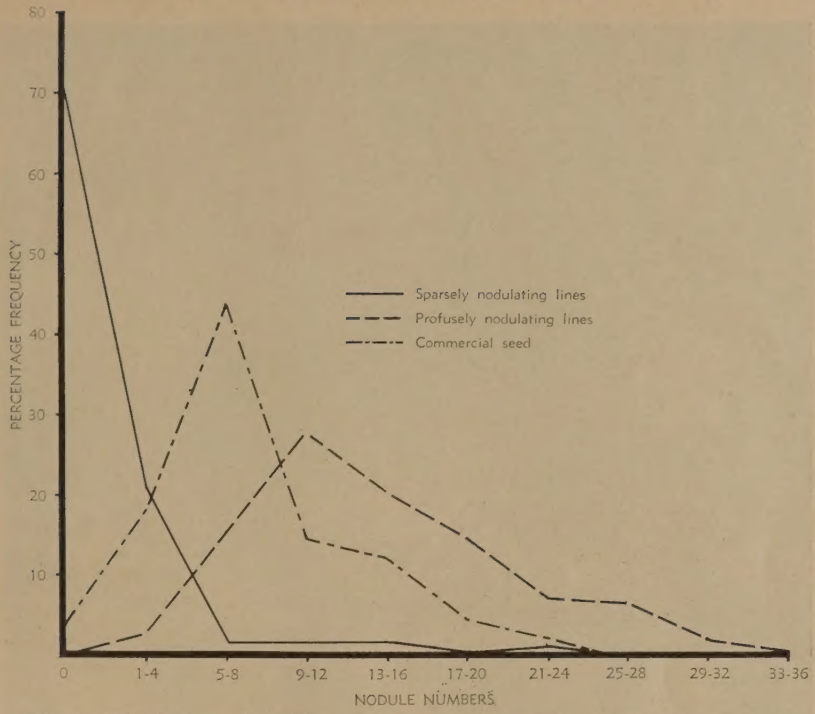

Fig 5.—Distribution of nodule numbers per plant with sparsely and profusely nodulating selections of *Centrosema pubescens*.

TABLE 3

NODULATION OF PLANT SELECTIONS BY FOUR RHIZOBIUM STRAINS

Rhizobium Strain	Sparsely Nodulating Selection		Commercial Seed		Profusely Nodulating Selection	
	Seed Inoculated	Seedling Inoculated	Seed Inoculated	Seedling Inoculated	Seed Inoculated	Seedling Inoculated
(*a*) Mean Number of Nodules per Plant						
QA549	3·3	1·2	11·6	12·2	22·5	14·7
QA837	11·0	7·5	13·2	11·2	15·5	15·8
QA869	8·5	6·3	6·0	6·5	17·7	7·7
QA870	9·2	8·5	7·4	8·8	9·9	7·0
Uninoculated	0					
(*b*) Mean Oven-dry Weight/Plant (mg)						
QA549	26	38	182	98	125	96
QA837	150	58	205	102	172	141
QA869	157	61	162	70	314	64
QA870	77	74	156	71	214	71
Uninoculated	41					

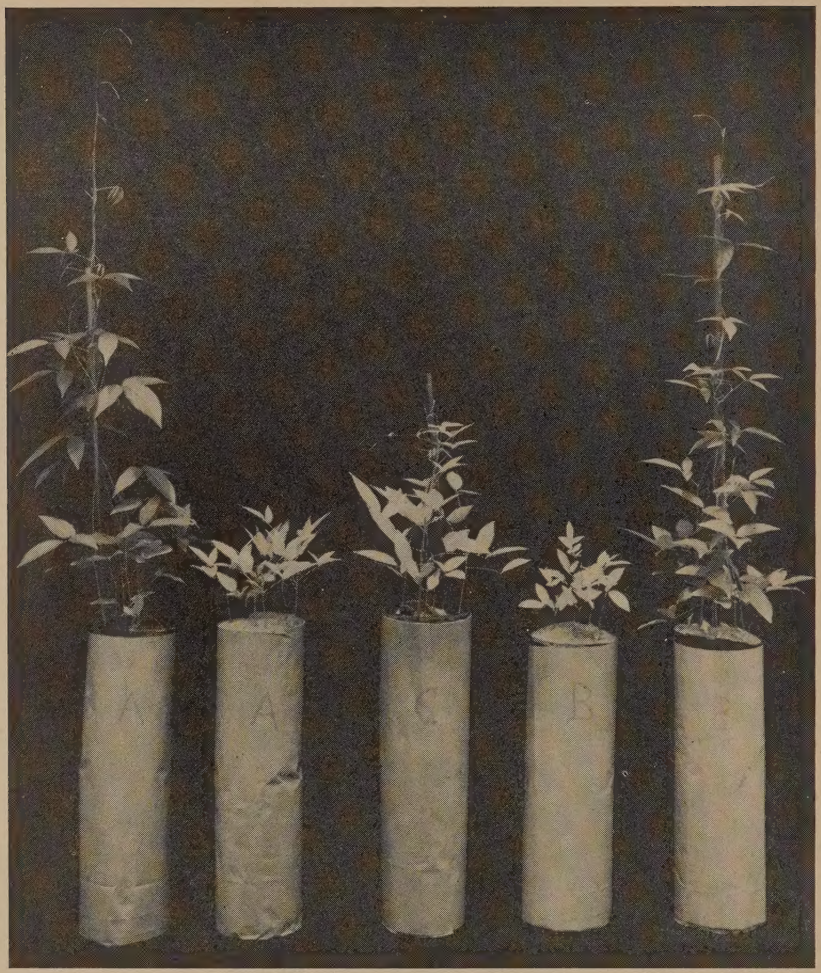

Fig. 6.—Growth of seedlings from profusely and sparsely nodulating selections of *Centrosema pubescens*. Left to right: (1) Profusely nodulating selections inoculated with QA523a. (2) Sparsely nodulating selections inoculated with QA523a. (3) Uninoculated. (4) Sparsely nodulating selections inoculated with QA549. (5) Profusely nodulating selections inoculated with QA549.

Despite variability due to uneven germination, the results after eight weeks (Table 3) showed conclusively that the S lines could be nodulated successfully by the use of Rhizobium strains QA837, QA869 and QA870. These nodulated all plants of all seed lots. In contrast, QA549 produced little nodulation and growth of S lines. These findings have been confirmed in other (unpublished) experiments by the authors.

There was an indication that with some Rhizobium strains growth of P lines may be greater than that of normal plants in commercial seed lots and successfully nodulated S lines.

IV. DISCUSSION

The results showed that marked variation in nodule numbers on *C. pubescens* in the field and glasshouse can be explained at least in part by the presence of sparsely and profusely nodulating lines in commercial seed lots. Evidence for a genetic factor in legume nodulation was advanced by Wilson, Burton, and Bond (1937); Nutman (1946) first demonstrated its importance in a series of intensive studies on red clover. *C. pubescens* is almost exclusively self-pollinated (Hutton 1960) and plant selections from within commercial seed breed almost completely true. It is probable that within commercial seed of this legume there are a number of stable lines with different nodulation responses. A significant difference in numbers of nodules formed by the P lines was shown.

Earlier studies (Bowen 1959*b*) have shown that the numbers of nodules formed is also a property of the Rhizobium strain. While most Rhizobium strains for *C. pubescens* nodulate the S lines only sparsely, the present studies demonstrate that some rhizobia can nodulate these reasonably well. There may yet be a tendency for the S lines to nodulate less than other lines and possibly produce less growth in a nitrogen-deficient medium but this needs further study.

While the experiment with the two Rhizobium strains QA523a and QA549 showed that P lines (profusely nodulating) produced no more growth than the normal plants of a commercial seed lot despite production of more nodules, the last experiment gave some indication that with other Rhizobium strains profuse nodulation may result in greater plant growth. Plant response in nitrogen-deficient substrate depends not on the number of nodules alone but on the total volume of actively fixing nodule tissue (Bowen 1959*b*). The interaction between nodule number and nodule size is complex and profusion of nodules may not always infer a decline in nodule size and loss of nitrogen-fixing activity per nodule. This is being studied further.

V. ACKNOWLEDGEMENTS

We wish to thank officers of the Biometrics Section for statistical analyses, the Ayr Regional Experiment Station for production of seed from the plant selections and the Photographic Section for the photography. The last portion of the study was made while one of us (G.D.B.) was employed by the Division of Soils, C.S.I.R.O., Adelaide.

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PEACH BROWN ROT INVESTIGATIONS IN QUEENSLAND

By K. N. Shea, B.Sc.*

SUMMARY

Blossom blighting is of no practical importance in Queensland. Most fruit infections appear to occur during a period of about a month before harvest.

Control of brown rot in dessert peaches was obtained with three sprays of captan at intervals of two weeks, the last being immediately before harvest.

I. INTRODUCTION

Brown rot (*Sclerotinia fructicola* (Wint.) Rehm) is, in seasons favourable to it, the most destructive disease of stone fruits in Queensland. Over the past decade a number of experiments have been carried out with a view to minimizing losses, and more recently the period during which infection takes place in Queensland has also been investigated. The present paper summarizes the results of this work.

Considerable variability in experiments with brown rot has been reported by Angell (1950) and Pont (1950) and is to be found in the work reported here. Pont in an unpublished report of the Queensland Department of Agriculture and Stock (1950) suggested that latent infection might account for some of the variable results obtained in field experiments. Wade (1951) also considered some latent infection to be involved and later (Wade 1956) developed this hypothesis further.

Jerome (1958) showed that peaches can carry large numbers of viable conidia on the surface and postulated latent contamination rather than latent infection.

II. MATERIALS AND METHODS

(a) Spraying Experiments

Blocks of peach trees were used, randomized as single-tree plots. At harvest time, fruit samples, normally of 25 fruit per tree, were collected and stored at room temperature for some days. During this period diseased fruit were counted and removed.

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The materials used were: lime sulphur (20·0% w v sulphur as polysulphides); thiram (80% w w, used at 0·12% active ingredient); ziram (80% w w, used at 0·12% active ingredient); captan (50% w w, used at 0·1% active ingredient); "zinc omadine" (50% w w of the zinc salt of pyridinethione 1 oxide, used at 0·1% active ingredient).

(b) Bagging Experiments

A series of trials aimed at determining the infection periods and their relative importance was commenced in 1954 and has continued to date.

Fruit were enclosed in individual bags of 0·0015 in. clear polythene ("Visqueen") held closed by rubber bands. When field inoculations were carried out, similar sleeves, open at both ends, were used and closed by rubber bands. Inoculations were made with a "Rega" Junior hand pneumatic spray using a water suspension of conidia from fresh sporing cultures.

These experiments fall into two groups, those without artificial inoculation and those with it.

Without artificial inoculation, the fruits were bagged in the field before probable infection times (empirically determined) and left until harvest. Then, still in their individual bags, they were harvested and stored at room temperature for a few days before being examined for brown rot.

Artifically inoculated fruit were inoculated at periods considered to be important for natural infection. Thereafter they were, in their individual sleeves, treated similarly to the uninoculated bagged fruit.

In all instances a final sample of 100 was sought and so a substantial allowance was made initially for storm and other losses. Nevertheless, high winds and other causes commonly removed most bags and sleeves applied early in the season.

III. EXPERIMENTAL RESULTS

(a) Spraying Experiments

When work in Queensland was reported by Pont (1950), the only suitable fungicides available were based on sulphur, and lime sulphur had been recommended for some time. Experimental work at that time was aimed at establishing spray concentrations and length of spraying period. A typical schedule at this time involved spray applications at fortnightly intervals for two to three months.

Other fungicides have since become available and it was found in 1952-53 that thiram was superior to ziram and to lime-sulphur (McKnight, unpublished report, Queensland Department of Agriculture and Stock, 1953). In the following season, captan proved significantly superior to both thiram and ziram.

One outcome of this work was the apparent value of a preharvest spray. In 1954-55 captan and thiram with and without a preharvest spray were included in a 13 x 3 randomized trial in a block of Golden Queen peaches. The preharvest spray was applied approximately 24 hr before harvest on February 26, 1955 and 11 days after the previous application, which was the end of either a 3-spray or a 6-spray schedule. The data relative to the preharvest spray are given in Table 1. Subsequent work has supported this result and the preharvest spray is now a standard recommendation in Queensland.

TABLE 1

EFFECT OF PREHARVEST SPRAY ON BROWN ROT DEVELOPMENT. GOLDEN QUEEN PEACHES, 1954–55

Treatment	Percentage of Brown Rot	
	Mean	Equiv.
Captan with preharvest spray	16·4	8·0
Captan without preharvest spray	21·3	13·2
Thiram with preharvest spray	17·3	8·8
Thiram without preharvest spray	34·0	31·2
Untreated	43·0	46·5
Necessary difference for significance (5%)	17·9	

In view of the constant trend of evidence that most infection in Queensland occurs during the ripening of the fruit, work in the later years has been directed to checking whether spraying with captan during the ripening period of about one month would give satisfactory control. Results of two of these trials are shown in Tables 2 and 3. In each case the last spray was applied a day before harvest. Under this condition no worthwhile advantage was obtained by spraying once a week instead of once every two weeks.

TABLE 2

EFFECT OF LATE SPRAYING ON BROWN ROT DEVELOPMENT. GOLDEN QUEEN PEACHES, 1958–59

Treatment		Percentage of Brown Rot	
		Mean	Equiv.
5 captan sprays, weekly		21·8	13·8
3 captan sprays, fortnightly		28·5	22·8
Untreated		60·3	75·5
Necessary differences for significance	5%	17·9	
	1%	24·8	

TABLE 3

EFFECT OF LATE SPRAYING ON BROWN ROT DEVELOPMENT. WIGGINS PEACHES, 1959–60

Treatment	Percentage of Brown Rot	
	Mean	Equiv.
5 captan sprays, weekly	29·1	23·6
3 captan sprays, fortnightly	22·5	14·6
2 Zn omadine sprays, fortnightly	25·5	18·6
Untreated	52·4	62·7
Necessary differences for significance 5%	19·2	
Necessary differences for significance 1%	26·2	

In 1959-60 the effect of dipping fruit in a fungicide prior to packing was tried. Captan and "Mycostatin" gave similar results, which were comparable with field spraying. Suitable equipment for dipping is not, however, at present found in Stanthorpe orchards.

(b) Bagging Experiments

Without Artificial Inoculation.—Table 4 shows the incidence of brown rot developing after harvest on fruit bagged in 1956-57. The differences are not statistically significant but there is some evidence of the similar trend noticed in spraying experiments of most infection occurring during ripening of the fruit.

TABLE 4

DEVELOPMENT OF BROWN ROT IN BAGGED UNINOCULATED WIGGINS PEACHES, 1956–57

Time Fruit Bagged	No. of Fruit	Percentage of Brown Rot
Flowering	29	13·3
End of fruit set	122	14·7
Start of ripening	107	29·9
Harvest	100	57·0

With Artificial Inoculation.—Table 5 shows the percentage of brown rot developing after harvest on fruit inoculated in 1956-57 and 1957-58 on two blocks of peaches, one of the variety Wiggins and the other of Golden Queen. As it is necessary to delay bagging flowers until fertilization has occurred, the "flowering" and "fruit set" times were combined in later years and the inoculation carried out at approximately petal fall. Results for 1958-59 and 1959-60 are given in Table 6.

TABLE 5

DEVELOPMENT OF BROWN ROT IN INOCULATED PEACHES

Time of Inoculation	1956–57				1957–58			
	Wiggins		Golden Queen		Wiggins		Golden Queen	
	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)
Flowering	40	5·0	1	0	6	0	0	0
End of fruit set ..	62	0·0	36	11·1	30	13·3	65	3
Start of ripening ..	70	45·7	73	17·8	74	2·7	80	31·7
Harvest	73	86·3	75	82·7	47	59·6	77	85·7

TABLE 6

DEVELOPMENT OF BROWN ROT IN INOCULATED PEACHES

Time of Inoculation	1958–59				1959–60			
	Wiggins		Golden Queen		Wiggins		Golden Queen	
	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)	No. of Fruit	Brown Rot (%)
Fruit set	66	0	10	20	17	59	7	14
Start of ripening ..	52	6	80	1	106	63	118	28
Harvest	28	71	38	79	100	100	100	98

These trials met with many vicissitudes and in no one year were the figures suitable for analysis. However, every year there has been the definite trend indicating most infection during the ripening period.

IV. GENERAL OBSERVATIONS

During the period 1951-1960 several detailed searches were carried out for apothecia of *S. fructicola*. None has been found. *S. fructicola* has, however, been obtained readily from surface washings off mummified peach fruit during the winter. Apothecia appear to be of little, if any, importance in the perpetuation of the disease in Queensland.

Blossom blighting has been seen once only (1954-55) in this decade and then it was of little importance. It would seem that this source of infection can safely be left out of consideration in Queensland control recommendations.

McKnight (unpublished report, Queensland Department of Agriculture and Stock, 1953) sampled leaves from a block of peach trees in which variations in incidence of brown rot were observed. Leaf analyses for potassium

were made in the Department's Chemical Laboratory. The results ranged from 51·5 to 77·9 m-equiv. per cent. (composite sample 62·1) for low brown rot and from 60·4 to 73·5 (composite sample 70·0) for high brown rot incidence. The differences were not significant.

V. DISCUSSION

Virtually the entire Queensland production of stone fruit is sold for table consumption. Most is sold in Brisbane and nearly all of the remainder in other east coast towns. There, in summer, the climate is normally warm and humid. Under such conditions brown rot can quickly cause serious loss in consignments. (Optimum temperature for growth of *S. fructicola* is 24°-26°C (Pont, unpublished report, Queensland Department of Agriculture and Stock, 1950)). It is therefore necessary that control measures continue to act during transport and marketing and also in the consumer's home. As the fungus spores profusely and the ripe fruit are so susceptible, it is necessary to market the fruit with a prophylactic coating of fungicide. Any such material, to be suitable, must leave no objectionable visible residue and must not be a health hazard.

Captan has given the best fungicidal control of the materials tried. Its effect has been consistent for several years. It satisfies the other requirements. A preharvest spray ensuring a fungicidal cover on the harvested fruit has given improved control on fruit that are stored for several days at summer temperatures.

To sum up—the most satisfactory commercial control under Queensland conditions has been obtained from captan used in the month before harvest, with the last spray a day before picking. Control measures against blossom blighting are not warranted.

No definite proof for or against a latent infection hypothesis has emerged but most of the results here reported show a constant trend indicating that most infection in Queensland occurs late in the life of the fruit, possibly during ripening.

VI. ACKNOWLEDGEMENTS

The field trials were carried out on the properties of Messrs. R. Lawer (Severnlea) and R. Smith & Sons (Ballandean). The biometrical analyses were the work of the Biometrics Section. This assistance is gratefully acknowledged.

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COMPARATIVE MORPHOLOGICAL STUDIES OF *HELIOTHIS* SPECIES (LEPIDOPTERA: NOCTUIDAE) IN QUEENSLAND

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SUMMARY

Studies of the external morphology of immature stages of the four *Heliothis* species present in Queensland have been made, and descriptions together with tables of important measurements are given. Some notes on adult morphology are also given. Similarities and differences among species are discussed, and keys to adults and immature stages are provided.

I. INTRODUCTION

Of the four *Heliothis* species in Queensland—*H. armigera* (Hubn.), *H. punctigera* Wallengr., *H. assulta* Gn. and *H. rubrescens* (Walk.)—the first three are pests attacking a wide range of crops, and quick recognition of all stages is therefore of some importance. These studies were carried out at Nambour during 1957-58.

II. GENERAL METHODS

Eggs, which are found on host surfaces, particularly on or near flowering parts (Figure 1), were examined *in situ*. Larvae were examined entire as suggested by Crumb (1956), after methods of mounting cuticles on slides as described by Balfour-Browne (1932) and Mukerji and Hukam Singh (1951) were found unsuitable owing to setal relations being disturbed by folds formed in the cuticle when pressed flat. Pupae, in a holder to prevent movement, were examined entire. Adults were killed with cyanide and set, while the genitalia were removed and mounted as described by Siverly (1947).

III. DESCRIPTIONS

(a) Eggs (Figure 1)

The following applies to the four species:—

Egg erect, nearly spherical, slightly flattened at summit and base, height and diameter equal. Chorion marked with 28-35 vertical ribs, most ribs entire, some branched. Micropyle in middle of summit surrounded by a smooth ribless area. Colour at oviposition pale or dark yellow. An irregular reddish-brown band encircling egg slightly above equator develops 2-3 days before larva emerges; entire colour changes to light-grey about 24 hr before larva emerges, with black head capsule of larva visible as a dark internal spot.

Additional data relating to the eggs of the four species are given in Table 1.

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Fig. 1.—Eggs of *H. armigera* on tobacco inflorescence. (After W. A. Smith 1952.)

TABLE 1

EGGS OF HELIOTHIS SPECIES

Species	Colour at oviposition	Diameter (mm) = Height		Number Measured
		Mean	Range*	
H. armigera	Pale yellow ..	0·51±·005	0·46–0·53	23
H. assulta	Pale yellow ..	0·47±·003	0·43–0·52	55
H. punctigera	Pale yellow ..	0·53±·004	0·50–0·56	21
H. rubrescens	Dark yellow ..	0·44±·002	0·41–0·48	77

* The complete range has been recorded from eggs by individual females.

(b) Larvae

Thirty to 60 in each instar were examined. In these descriptions, nomenclature of the hypopharynx follows Gilbert (1939), of the setae Hinton (1946) and of colour areas Crumb (1956).

The following applies to the four species (except where indicated):—

(1) Head

Frons broadly triangular, slightly longer than wide, marked by several irregular transverse furrows, mandible (Figure 2) 4- or 5-toothed with ribs on oral surface extending from tooth bases to two-thirds mandible depth; hypopharynx (Figure 3) with lingula clothed with small erect spines, blade of maxillula with 8-12 serrations on free margin, spinneret length 4 times width at base.

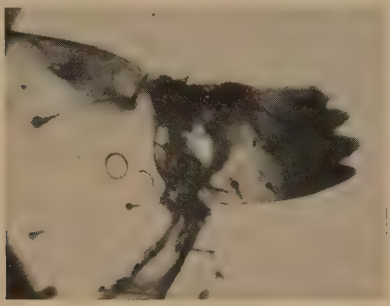

Fig. 2.—Mandible of *H. armigera* (× 72).

Fig. 3.—Hypopharynx of *H. armigera* (× 15).

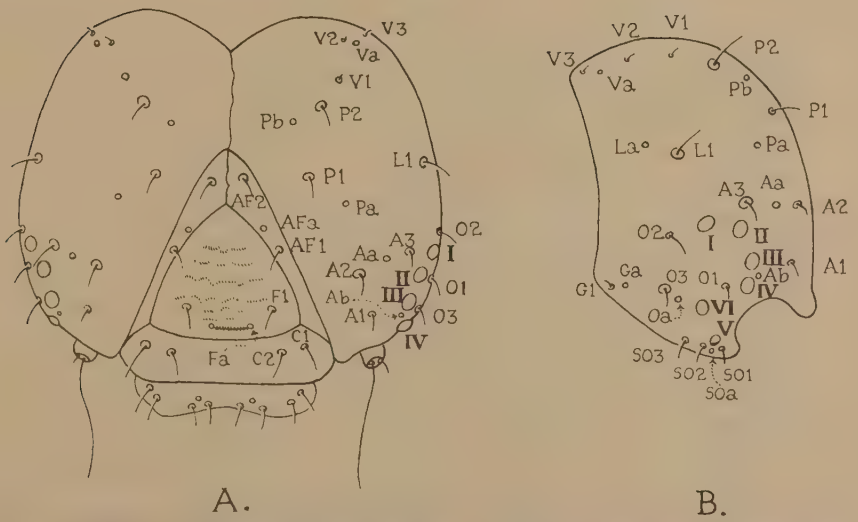

Fig 4.—Head of *H. armigera,* showing chaetotaxy (× 25). A, front view; B, lateral view. (Lettering after Hinton 1946).

Chaetotaxy (Figure 4) of general Noctuid pattern (see also Crumb 1929). Puncture *Afa* closer to seta *Af1* than to *Af2*. Punctures *Fa* joined across midline by pigmented furrow. Puncture *Va* nearly equidistant from microsetae *V2* and *V3*, on slightly lower level. *Pa* between *P1* and *A3*, twice as far from *A3* as from *P1*. *Aa* between and equidistant from *A2* and *A3*. *Ga* between *G1* and *O3*, much closer to *G1*. *SOa* between and equidistant from *SO2* and *SO1*. *Oa* between *O3* and ocellus *VI*, slightly closer to *O3*; ocellus *I* between and equidistant from *O2* and *A3*.

Colour of first instar black or dark-brown, of later instars light-brown to green, with a fairly constant pattern of darker spotting (Figure 5).

Fig. 5.—Head of *H. armigera* (× 20), showing pattern of dark spotting.

TABLE 2

HEAD WIDTHS (mm) OF *Heliothis* SPECIES

Instar	—	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1 ..	Mean ..	0·27±·003	0·25±·003	0·24±·002	0·27±·003
	Range ..	0·25–0·31	0·23–0·31	0·22–0·26	0·24–0·29
2 ..	Mean ..	0·45±·005	0·46±·006	0·40±·005	0·44±·005
	Range ..	0·40–0·50	0·41–0·53	0·35–0·45	0·39–0·49
3 ..	Mean ..	0·73±·02	0·86±·01	0·65±·013	0·75±·011
	Range ..	0·60–0·85	0·75–0·95	0·61–0·78	0·70–0·85
4 ..	Mean ..	1·13±·02	1·56±·01	1·07±·025	1·39±·016
	Range ..	0·92–1·25	1·40–1·70	0·90–1·35	1·30–1·65
5 ..	Mean ..	1·80±·07	2·55±·022	1·61±·021	2·25±·03
	Range ..	1·55–1·95	2·20–2·60	1·45–1·75	1·90–2·40
6 ..	Mean ..	2·72±·02	..	2·45±·023	..
	Range ..	2·20–3·0		2·30–2·60	

Head widths are given in Table 2. Under the temperatures and humidities experienced at Nambour, *H. armigera* and *H. punctigera* had 6 instars, *H. assulta* and *H. rubrescens* 5. As the head widths of first and last instars of all species are similar, there are noticeable species differences in ratios according to Dyar's Law (see Table 3).

TABLE 3

RATIOS OF HEAD CAPSULE WIDTHS

Instar	—	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1–2 ..	Mean ..	1·69	1·86	1·67	1·78
	Range ..	1·54–1·80	1·7–2·1	1·54–1·78	1·67–1·90
2–3 ..	Mean ..	1·53	1·80	1·6	1·71
	Range ..	1·4–1·82	1·7–1·93	1·43–1·75	1·63–1·78
3–4 ..	Mean ..	1·51	1·88	1·55	1·80
	Range ..	1·3–1·72	1·72–2·06	1·23–1·85	1·62–2·0
4–5 ..	Mean ..	1·51	1·67	1·60	1·64
	Range ..	1·40–1·62	1·5–1·82	1·25–1·76	1·58–1·77
5–6 ..	Mean ..	1·55	..	1·50	..
	Range ..	1·44–1·62		1·35–1·64	
Average for all instars		1·56	1·80	1·58	1·73

(2) Thorax and Abdomen

Length 10-12 times width. Spiracles conspicuous, present on prothorax and abdominal segments 1-8, height of spiracle approximately 1½ times width. Prolegs on abdominal segments 3, 4, 5, 6 and 10; crochets biordinal, in numbers varying from 11 to 19 on each proleg. Skin covered with minute spinules (Figure 6), a distinguishing feature of the genus.

Chaetotaxy (Figure 7) similar in all instars. On prothorax, setae XD1, XD2, D1, D2 and MXD1 located on prothoracic shield; setae SD1 and SD2 sometimes present, sometimes only SD1. Setae L1 and L2 anterior to spiracle, tubercles sometimes joined. Tubercles of setae SV1 and SV2 always joined. On meso- and meta-thorax, setae D1, D2, SD1 and SD2 in vertical row, MD1 directly anterior to D2. L1 directly above L2. MSD1 anterior to and slightly above MSD2. MV1 anterior to and in horizontal line with SV1. On abdominal segments, D2 below and posterior to D1, SD2 microscopic, anterior to and level with top of spiracle in segment 1, moving to a slightly lower position in successive segments until level with middle of spiracle in segment 8. L1 directly posterior to spiracle in all segments except 7, where it is just below line of spiracle. Microseta MV1 anterior to L3 in all segments.

Fig. 6.—Photomicrograph of skin (abd. seg.1), showing minute spinules, spiracle and adjacent setae. Microseta opposite arrow (X 60).

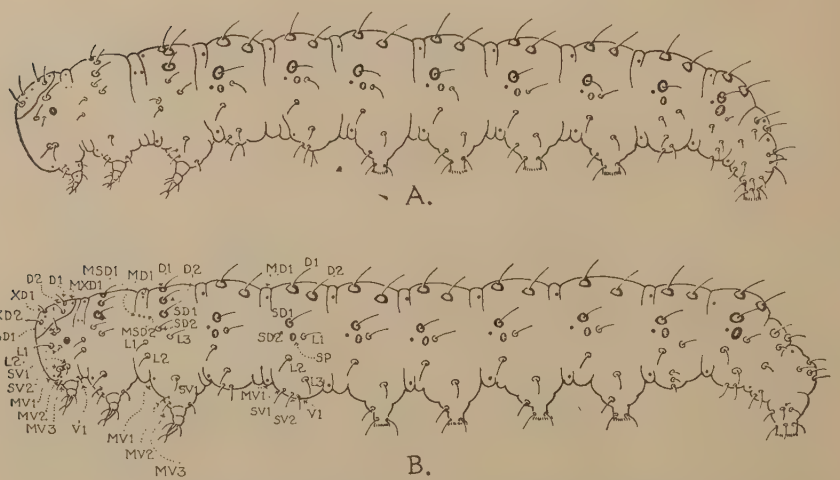

Fig. 7.—Larvae, showing chaetotaxy (× 3). Microsetae indicated by dots. A, *H rubrescens;* B, *H. armigera.* (Lettering after Hinton 1946).

Specific variation occurs in the size of the tubercles of the dorsal series of setae. This can be determined for any larva by finding the ratio of the vertical diameter of the tubercle of seta SD1 to the vertical diameter of the spiracle in the same segment. This ratio in abdominal segments 1 and 7 for the four species is given in Table 4.

TABLE 4

RATIO OF VERTICAL DIAMETER OF TUBERCLE SD1 TO VERTICAL DIAMETER OF SPIRACLE ON ABDOMINAL SEGMENTS 1 AND 7

Abdominal Segment	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
1	1·2 : 1–1·5 : 1	1·5 : 1–2·0 : 1	1·2 : 1–1·5 : 1	1·5 : 1–2·0 : 1
7	0·8 : 1–0·9 : 1	1·25 : 1–1·5 : 1	0·8 : 1–0·9 : 1	1·25 : 1–1·75 : 1

Some setal aberrations are common. On the prothorax seta SD1 is often missing, and seta XD2 is sometimes duplicated. On thoracic and abdominal segments D1 is often missing and D2 duplicated. Other less common aberrations involving loss or duplication of setae have been recorded.

Internal (background) colour of larvae greyish-white in first instar, varying from green to pinkish-brown in later instars. Dark-brown or black pigmentation present on prothoracic shield and setigerous tubercles in all instars, present over much of the body surface in all instars except the first in longitudinal anastamosing lines with intensity of pigmentation varying in the different body areas as follows: dorsal area extending from midline to just above seta D1 in all segments, heavily pigmented; subdorsal area lightly pigmented, extending from lower edge of dorsal area to seta SD1 on thoracic segments, to seta D1 in abdominal segments; supraspiracular area heavily pigmented, extending from lower edge of subdorsal area to just above spiracle on prothorax, to seta L3 on meso- and meta-thorax, to just above spiracle in abdominal segments with seta L1 included by an undulation in lower edge; subspiracular area a distinct white band with very light brown markings, sometimes with a pinkish suffusion at inter-segmental junction, extending from lower edge of supraspiracular area to midway between setae L1 and SV2 on prothorax, to seta L2 on other segments. Microseta SD2 on abdominal segments in subspiracular area usually marked by a dark spot.

In some aberrant forms of later instars, the body completely lacks dark pigmentation; in others, prothoracic shield and setigerous tubercles only are darkly pigmented.

(c) Pupae (Figures 8 and 9)

The following applies to all species:—

Epicranial suture absent; labial palp one-quarter to one-fifth length of maxilla; maxilla length of forewing; femur of prothoracic leg visible between

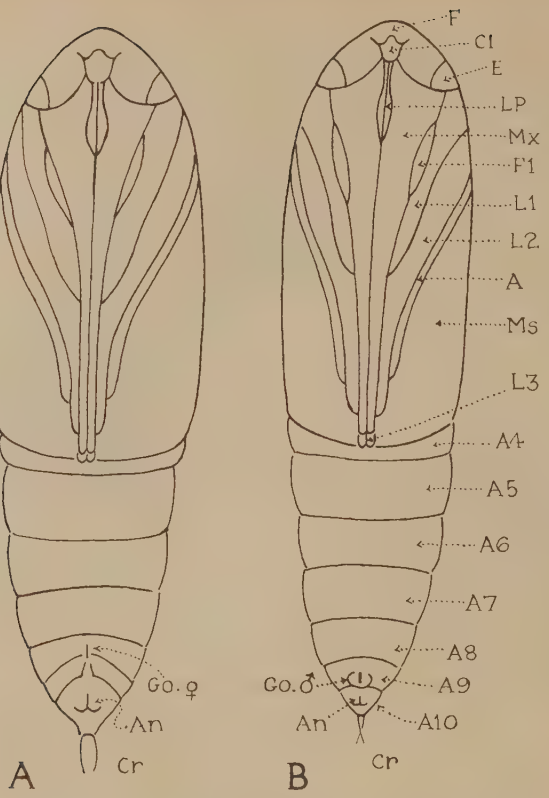

Fig. 8.—Ventral views of pupae (× 5). A, *H. armigera* ♀; B. *H. punctigera* ♂. A, antennae; A4–10, abdominal segments 4–10; An, anus; Cl, clypeus; Cr, cremaster; E, eye; F, frons; F1, femur of prothoracic leg; Go ♂, male gonopore; Go ♀, female gonopore; L 1–3, pro-, meso-, and meta- thoracic legs; LP, labial palp; MS, mesothoracic wing; Mx, maxilla.

maxilla and tibia-tarsus of prothoracic leg, which is half length of maxilla; mesothoracic legs almost length of maxilla; tip of metathoracic leg just protruding below maxilla; antenna six-sevenths length of maxilla. Metathoracic wing covered by mesothoracic wing on ventral surface. Cremaster with 2 spines, tips usually crossed, rarely 1 or no spines present. Anus slit-like, on abdominal segment 10. Male gonopore small, on segment 9, edged by lateral swellings. Female gonopore small, midway between segments 8 and 9. A slight sex difference in profile of terminal abdominal segments (Figure 9). Cuticle of movable abdominal segments pitted above spiracles, smooth below.

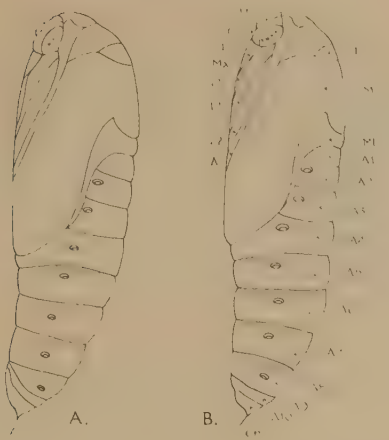

Fig. 9.—Lateral views of pupae (× 5·5). A, *H. armigera* ♀; B, *H. punctigera* ♂. (Lettering as in Fig. 8.) A 1–4, abdominal segments 1–4; Mt, metathoracic wing.

Colour at first translucent green, slowly changing to dark-brown as cuticle hardens. Tips of cremaster spines transparent. Several days after pupation three dark spots appear in an oblique line in eye. Colour pattern of adult visible through pupal cuticle several days before emergence.

The distance between the outer edges of the cremaster spines at the junction with cremaster differs among species (Figure 10) and is given in Table 5.

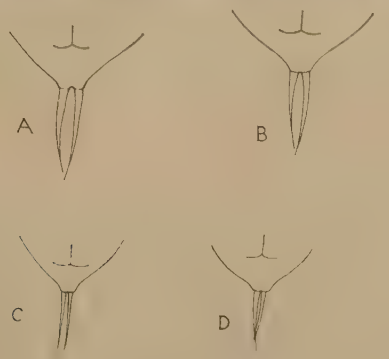

Fig. 10.—Pupal cremaster spines (× 26). A, *H. armigera;* B, *H. assulta;* C, *H. punctigera;* D, *H. rubrescens.*

TABLE 5

DISTANCE BETWEEN OUTER EDGES OF CREMASTER SPINES AT JUNCTION WITH CREMASTER

Measurement (mm)	*H. armigera*	*H. assulta*	*H. punctigera*	*H. rubrescens*
Mean	0·28 ± ·003	0·22 ± ·002	0·17 ± ·002	0·10 ± ·008
Range	0·22 to 0·39	0·18 to 0·28	0·14 to 0·20	0·12 to 0·20

(d) Adults

The four species have been redescribed by Common (1953); the following are additional notes from bred material.

(1) H. armigera

Wings.—Male and female (Figure 11A): Subterminal line usually distinct, strongly angled outwards on vein R5, M3, Cu1a and Cu1b to form three well-defined dentations as in *H. assulta*.

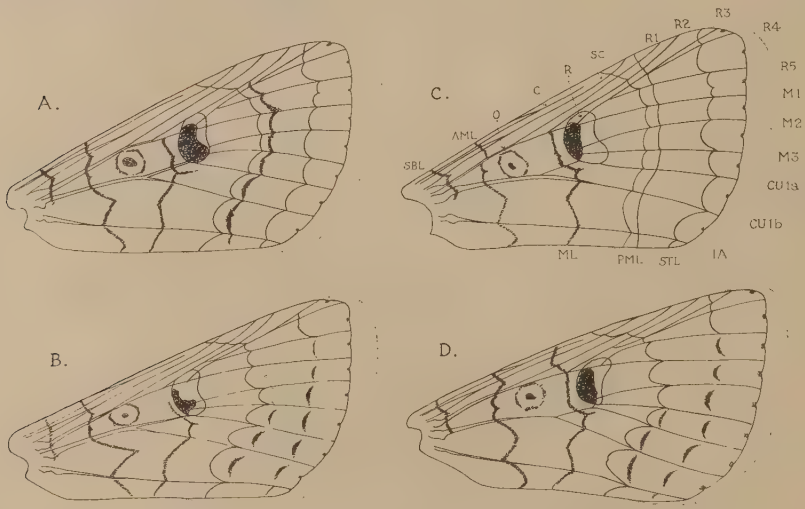

Fig. 11.—Forewings, showing venation and main markings (× 6·5). A, *H. armigera;* B, *H. punctigera;* C, *H. assulta;* D, *H. rubrescens.* 1A, C, Cula, Cu1b, M1, M2, M3, R1, R2, R3, R4, 55, Sc, veins; AML, antemedial line; ML, medial line; O, orbicular; PML, postmedial lines; R, reniform; SBL, sub-basal line; STL, subterminal line.

Genitalia.—Male (Figure 12B): Short backwardly directed thorn in distal orifice of adeagus variable in size and amount of sclerotization, often difficult to find. Thorn sometimes double (Figure 13). *Female:* Some variation in extent of spinulation of inner surface of bursa seminalis, some specimens very lightly spined.

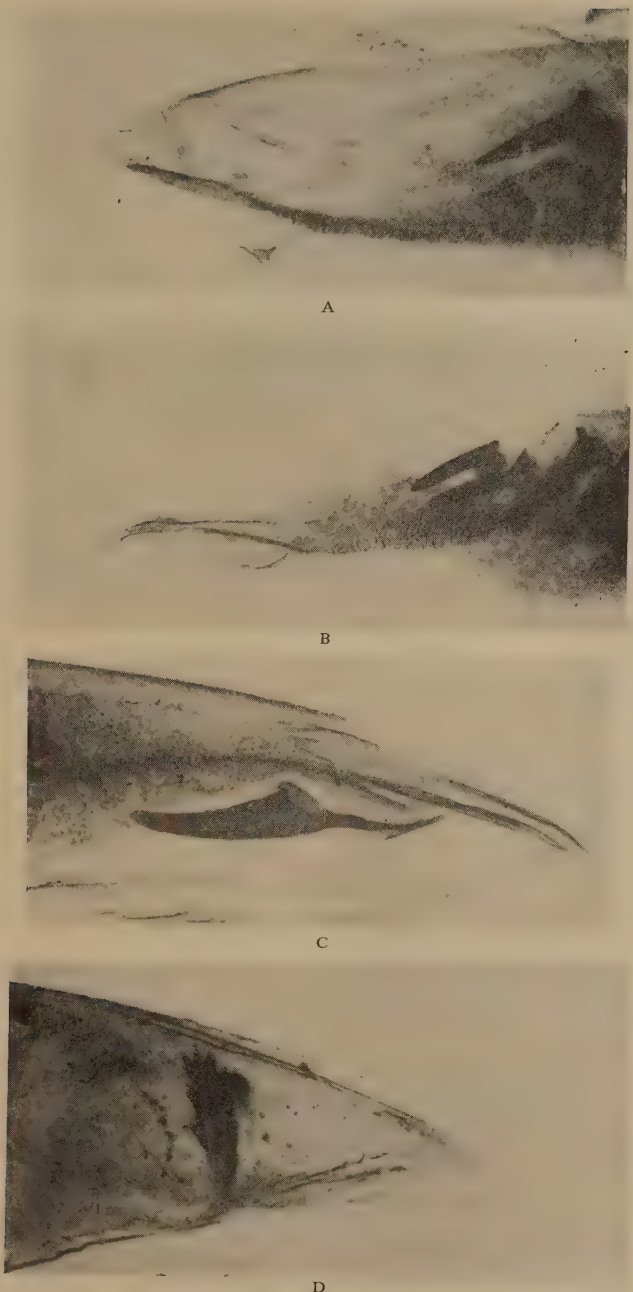

Fig. 12.—Tips of adeagi, showing sclerotized processes. A, *H. armigera* (× 90); B, *H. assulta* (× 90); C., *H. punctigera* (× 80); D, *H. rubrescens* (× 80).

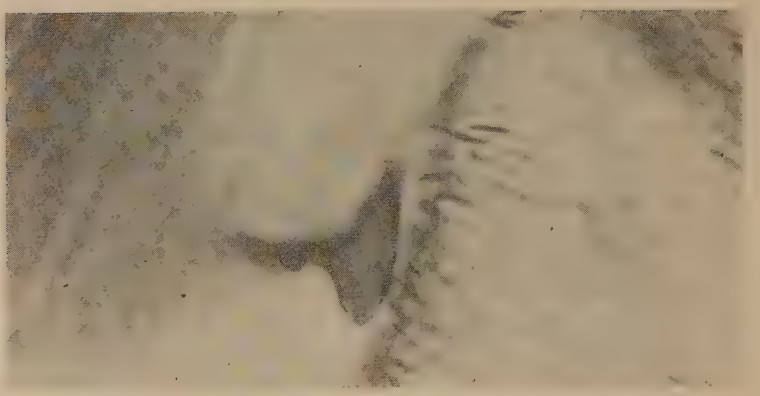

Fig. 13.—Double "thorn" in tip of adeages of *H. armigera* (× 400).

(2) H. assulta

Wings.—Male and female (Figure 11B): Subterminal fascia on underside of forewing identical with that of *H. armigera,* covered from vein M1 to costa by a reddish suffusion. This suffusion may be abraded in old specimens. *Male:* Ground colour of forewings ocherous grey with a yellowish tinge. *Female:* Ground colour of forewings orange-brown to reddish-brown.

(Common (1953) apparently based his redescription on abraded or faded specimens of both sexes.)

Genitalia.—Male: Definite area of sclerotization in distal orifice of adeagus, produced into a thorn as in *H. armigera* (Figure 12B), but relatively smaller and sometimes difficult to find.

(3) H. punctigera

Wings.—Male and female (Figure 11C): Post-medial lines usually present but indistinct, inner line angled sharply on veins R5, M1, M2, M3, Cu 1 a, Cu 1 b and 1A; outer line barely distinguishable. *Female:* Colour of forewing varies from reddish-brown to light-brown.

(4) H. rubrescens

The "pink form" described by Common (1953) is one extreme of a wide range of colour variation within the species.

IV. DISCUSSION

Species show a remarkable similarity in the immature stages and separation of all species in any one of these stages is not possible.

The only specific difference at any time in the eggs is that those of *H. rubrescens* are dark-yellow at oviposition (Table 1).

The larvae of *H. armigera* and *H. punctigera* can be separated from those of *H. assulta* and *H. rubrescens* by the size of the dorsal series of setigerous tubercles (Table 4), other important differences being in normal instar number and ratios of head capsule widths (Tables 2 and 3). *H. rubrescens* larvae, which have black tubercles, may be distinguished from *H. assulta* larvae, which have dark-brown tubercles, but larvae of *H. armigera* and *H. punctigera* are identical in all characters examined.

The pupae differ specifically in the spacing of the cremaster spines (Table 5), but the differences can be used for species separation only if the larva from which a pupa developed is known, in which case only *H. armigera* and *H. punctigera* need be separated. The pupae of *H. armigera* have widely spaced spines, with the distance between their outer edges at junction with the cremaster always greater than 0·22 mm, while pupae of *H. punctigera* have closely spaced spines with the corresponding measurement less than 0·20 mm.

In contrast to the immature stages, the adults are readily separable on many characters, as discussed by Common (1953). Many basic similarities are evident, however, and care is needed if incorrect identifications are to be avoided. Forewing colours are similarly variable in all species: those of females vary from pink to shades of brown, those of males are shades of grey. In *H. punctigera* the distinction in forewing colour between sexes is least marked, many females being pale brown while males tend to fawn rather than grey.

Hindwing colours provide the most consistent differences among species. The basal colour in *H. armigera* and *H. punctigera* is white with a greyish brown suffusion, while in *H. assulta* and *H. rubrescens* the colour is yellow or yellowish orange. A pale spot of variable extent is present in the black terminal fascia of *H. assulta* and *H. armigera,* but no such spot occurs in *H. punctigera* and *H. rubrescens.*

Forewing markings are basically similar in all species (Figure 11), with extensive intraspecific variation in shape and clarity of outline. The subterminal line in *H. punctigera* and *H. rubrescens* is distinguishable only as some darker shading, but in *H. assulta* and *H. armigera* is well marked, being angled to form well-defined dentations on veins R5, M2, Cu1a and Cu1b, but the depths of the dentations vary considerably in *H. armigera.* The post-medial line is distinctly double in all species, but in *H. punctigera* and *H. rubrescens* the outer line is reduced to a light shading. The inner line is angled in all species to form dentations on veins R5, M1, M2, M3, Cu1a, Cu1b and 1A, the dentations being deep in *H. rubrescens* and *H. punctigera,* less deep in *H. armigera* and shallow in *H. assulta.* Other transverse lines, orbicular and reniform markings are variable in all species, and are least distinct in *H. punctigera.*

The patterns of the under-surfaces of the wings are similar, but the suffusion covering the costal margins of the subterminal fasciae of both wings is only faintly pink in *H. punctigera.*

Differences in the genitalia are consistent, and serve to identify species with certainty. In the males the shape of the sclerotized process in the distal orifice of the adeagus (Figure 12) immediately distinguishes *H. punctigera* and *H. rubrescens,* while *H. assulta* and *H. armigera,* which have similarly shaped processes, may be distinguished by the cornuti, which are smaller and more numerous in *H. assulta* than in *H. armigera.* In the female genitalia, the spines on the inner surface of the bursa seminalis distinguish *H. armigera* and *H. punctigera* from *H. assulta* and *H. rubrescens,* which lack spines, the cup-shaped genital plate of *H. armigera* is distinct from the parallel-sided plate of *H. punctigera,* while the lack of spiral coiling of the bursa seminalis of *H. rubrescens* distinguishes this species from *H. assulta.*

V. KEYS

(*a*) Eggs

1. Eggs pale yellow at oviposition ..... *H. armigera, H. assulta, H. punctigera*
   Eggs dark yellow at oviposition ..... *H. rubrescens*

(*b*) Larvae

1. Vertical diameter of tubercle of seta SD1 on abdominal segment 7 much greater than that of spiracle in same segment 2
   Vertical diameter of tubercle of seta SD1 in abdominal segment 7 less than, rarely the same as, that of spiracle in same segment .. *H. armigera* and *H. punctigera*
2. Tubercle pigment black ..... *H. rubrescens*
   Tubercle pigment brown (sometimes dark brown) ..... *H. assulta*

(*c*) Pupae of *H. armigera* and *H. punctigera*

1. Distance between outer edges of cremaster spines at junction with cremaster greater than 0·22 mm ..... *H. armigera*
   Distance as measured above less than 0·20 mm ..... *H. punctigera*

(*d*) Adults

Males

1. Basal area of hindwing yellow or orange, without greyish suffusion .. 2
   Basal area of hindwing whitish, suffused with grey or greyish brown 3

2. (1) Subterminal line indistinct, no pale marginal spot in terminal fascia of hindwing; adeagus with distinct spiny process in distal orifice of adeagus; cornuti of adeagus small and poorly developed ..... *H. rubrescens*

   Subterminal line of forewing forming 3 well defined dentations on veins M3, Cu1a, Cu1b; pale marginal spot in terminal fascia of hindwing; adeagus with small thorn in distal orifice; cornuti of adeagus large ..... *H. assulta*

3. (1) Forewings with indistinct transverse lines, no pale marginal spot in terminal fascia of hindwing; adeagus with long backwardly-directed spine in distal orifice ..... *H. punctigera*

   Forewings with distinct transverse lines, pale marginal spot in terminal fascia of hindwing; adeagus with small thorn in distal orifice ..... *H. armigera*

Females

1. Basal area of hindwing ochreous yellow or orange, without greyish suffusion; inner surface of bursa seminalis without clothing of minute spines 2

   Basal area of hindwing whitish, suffused with grey or greyish brown; bursa seminalis clothed internally with minute spines 3

2. Subterminal line of forewing indistinct, no pale marginal spot in terminal fascia of hindwings; bursa seminalis not spirally coiled ..... *H. rubrescens*

   Subterminal line of forewing distinct with well defined dentations on veins M3, Cu1b, terminal fascia of hindwing with pale marginal spot; bursa seminalis spirally coiled ..... *H. assulta*

3. (1) Transverse lines on forewing indistinct, terminal fascia of hindwing without pale marginal spot; genital plate with parallel sides ..... *H. punctigera*

   Transverse lines on forewing distinct, terminal fascia of hindwing with pale marginal spot; genital plate cup-shaped with sloping sides ..... *H. armigera*

VI. ACKNOWLEDGEMENT

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QUEENSLAND DISTRIBUTIONS AND HOST RECORDS FOR *HELIOTHIS* SPECIES (LEPIDOPTERA: NOCTUIDAE)

By T. H. Kirkpatrick, B.Sc.*

SUMMARY

Distributions and hosts of the four *Heliothis* species in Queensland are given.

***H. armigera* (Hubn.), *H. assulta* Gn., *H. punctigera* Wallengr. and *H. rubrescens* (Walk.) occur along the east coast and up to 100 miles inland wherever suitable host plants are available. In inland areas, only *H. punctigera* occurs regularly.**

All species occur mainly in the September-April period. Larvae prefer the reproductive parts of their hosts as food.

***H. armigera* is recorded from 23 hosts, *H. punctigera* from 15, *H. assulta* from 3 and *H. rubrescens* from 1. *H. armigera* and *H. punctigera* have similar host ranges, and although mixed populations often occur the presence of two species has not affected control.**

***H. assulta* is important as a pest of cape gooseberries only, and in the absence of suitable control measures is a limiting factor in production of this crop during the warmer months.**

I. INTRODUCTION

Common (1953) pointed out that in Australia many records of crop damage by *Heliothis armigera* (Hubn.) involved at least another species, *Heliothis punctigera* Wallengr., and possibly also *Heliothis assulta* Gn. and *Heliothis rubrescens* (Walk.). As all these species occur in Queensland, the first three as economic pests, a detailed knowledge of distributions and hosts is desirable.

Work on this project commenced in 1957.

II. METHODS

Extensive field collections of larvae were made in the vicinities of Ayr, Rockhampton, Nambour, Brisbane, and St. George, with lesser collections from many other parts of the State. These larvae were reared to maturity by methods to be detailed elsewhere, and the resulting adults identified.

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Adults reared from specific hosts by earlier workers and placed in the entomological collection of the Department of Agriculture and Stock have been identified and the relevant information included in the host lists.

Adults attracted to light have also been collected from many centres, and have been used to extend distribution records.

Host records are presented as two lists. In the first, hosts in alphabetical order are placed under the relevant species. Parts of hosts normally attacked and periods when feeding has been recorded are given. In the second, *Heliothis* species are listed under hosts.

III. DISTRIBUTIONS

Locality records are given in Figure 1. All species occur in coastal areas and up to at least 100 miles inland where suitable hosts occur. In western areas, only *H. punctigera* appears regularly on hosts, but adults of *H. rubrescens* have been attracted to light.

IV. HOST LISTS

(a) Heliothis species—Hosts

Heliothis armigera

Aizoaceae

Trianthema portulacastrum L. (black pigweed). January, February.

Caryophyllaceae

Dianthus caryophyllus L. (carnation). November. Flower buds.

Compositae

Gerbera jamesonii Bolus (gerbera). December. Flower buds and flowers.

Helianthus annuus L. (sunflower). June, July. Seedheads and flowers. These records from North Queensland.

Lactuca sativa L. (lettuce). May, June, November. Hearts.

Cruciferae

Brassica oleracea L. (cabbage). May. Hearts and young leaves.

Gramineae

Panicum miliaceum L. (French millet). March. Heads.

Sorghum spp. (grain sorghum). February to May. Heads.

Zea mays L. (maize). November to May, August. Young ears.

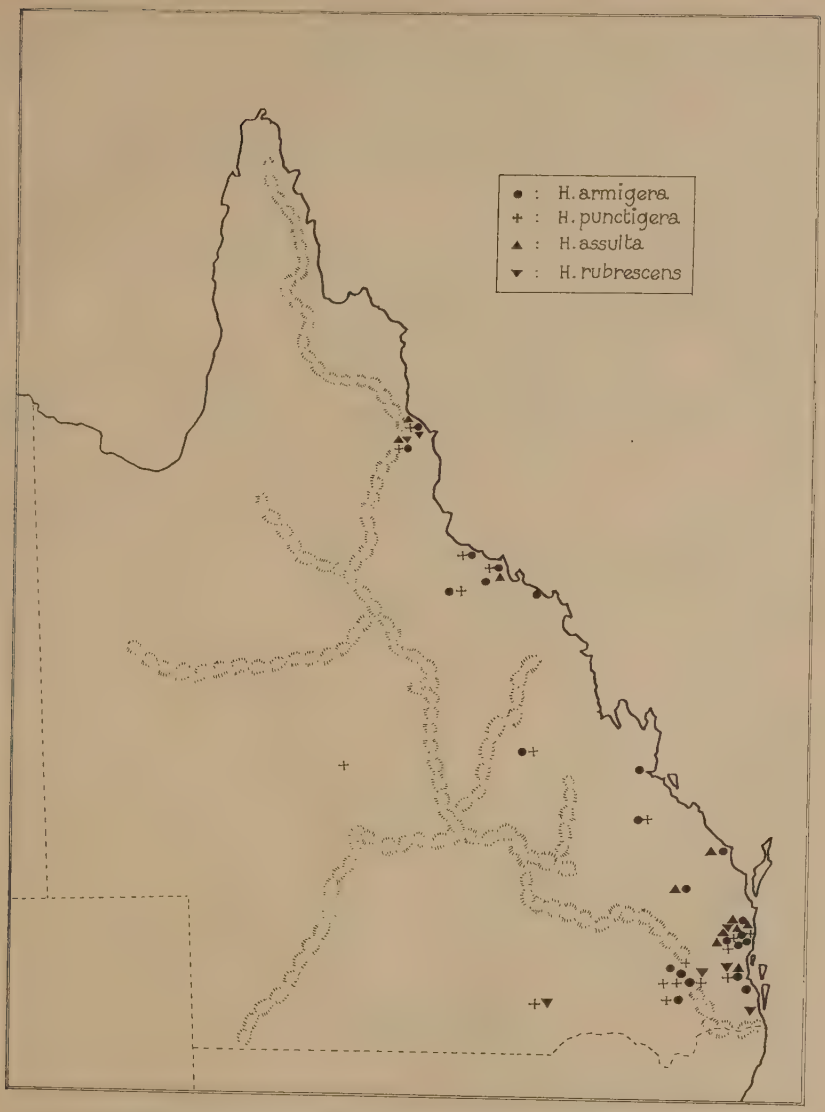

Fig. 1.—Map showing recorded distribution of species of *Heliothis* in Queensland.

Iridaceae

Gladiolus sp. (gladiolus). December. Flower buds.

Leguminosae

Cajanus cajan L. (pigeon pea). May, July. Pods.

Medicago denticulata Willd. (burr medic). September. Young leaves.

Phaseolus vulgaris L. (French bean). April, May, October. Pods.

Pisum sativum L. (garden pea). September, November. Pods.

Linaceae

Linum usitatissimum L. (linseed). September, October. Seedheads.

Malvaceae

Gossypium hirsutum L. (cotton). January to April, August. Bolls and squares.

Hibiscus esculentus L. (okra). January. Bolls.

Musaceae

Musa acuminata Colla (Cavendish banana). May. Young leaves. An isolated record only.

Rosaceae

Fragaria × *ananassa* Duchesne (strawberry). May, June, September, October. Young fruit.

Rutaceae

Citrus sinensis Osbeck (orange). June, October. Young leaves and fruit.

Solanaceae

Lycopersicon esculentum Mill. (tomato). January, April, May, November. Fruit.

Nicotiana tabacum L. (tobacco). November to January, March, June. Seed pods, young leaves.

Vitaceae

Vitis vinifera L. (grape). May. Fruit. An isolated record.

Heliothis assulta

Solanaceae

Lycopersicon esculentum Mill. (tomato). April. Fruit. In the single instance recorded, these larvae had evidently migrated from an adjacent eaten-out gooseberry patch.

Physalis minima L. (wild gooseberry). November to April. Young fruit. This host is infested invariably.

Physalis peruviana L. (cape gooseberry). August to April. Young fruit. This host is usually infested, but numbers are low in winter-grown crops.

Heliothis punctigera

Aizoaceae

Trianthema portulacastrum L. (black pigweed). January.

Caryophyllaceae

Dianthus caryophyllus L. (carnation). November. Flower buds.

Compositae

Carthamus tinctorius L. (safflower). October. Seedheads.

Xanthium pungens Wallr. (Noogoora burr). May. Young fruits.

Cucurbitaceae

Citrullus vulgaris Schrad. (watermelon). October. Shoots.

Iridaceae

Gladiolus sp. (gladiolus). December. Flower buds.

Leguminosae

Medicago sativa L. (lucerne). October-December. Flowers, pods, leaves.

Pisum sativum L. (garden pea). October. Pods.

Trifolium repens L. (white clover). October. Young leaves. This host damaged by larvae of 1st spring generation.

Linaceae

Linum usitatissimum L. (linseed). September to November. Seedheads.

Malvaceae

Gossypium hirsutum L. (cotton). December to March. Bolls.

Rosaceae

Fragaria × *ananassa* Duchesne (strawberry). September, November. Young fruit.

Scrophulariaceae

Antirrhinum majus L. (snapdragon). December. Flowers.

Solanaceae

Lycopersicon esculentum Mill. (tomato). November, December. Fruit.

Nicotiana tabacum L. (tobacco). January, November, December. Seed pods, young leaves.

Heliothis rubrescens

Compositae

Sigesbeckia orientalis L. (Indian-weed). March to May.

(b) Hosts—Heliothis species

Botanical Name	Common Name	Species Recorded
Aizoaceae		
Trianthema portulacastrum L.	Black pigweed	*H. armigera*
		H. punctigera
Caryophyllaceae		
Dianthus caryophyllus L.	Carnation	*H. armigera*
		H. punctigera
Compositae		
Carthamus tinctorius L.	Safflower	*H. punctigera*
Gerbera jamesonii Bolus	Gerbera	*H. armigera*
Helianthus annuus L.	Sunflower	*H. armigera*
Lactuca sativa L.	Lettuce	*H. armigera*
Sigesbeckia orientalis L.	Indian-weed	*H. rubrescens*
Xanthium pungens Wallr.	Noogoora burr	*H. punctigera*
Cruciferae		
Brassica oleracea L.	Cabbage	*H. armigera*
Cucurbitaceae		
Citrullus vulgaris Schrad.	Watermelon	*H. punctigera*
Gramineae		
Panicum miliaceum L.	French millet	*H. armigera*
Sorghum spp.	Grain sorghum	*H. armigera*
Zea mays L.	Maize	*H. armigera*
Iridaceae		
Gladiolus sp.	Gladiolus	*H. armigera*
Leguminosae		
Cajanus cajan L.	Pigeon pea	*H. armigera*
Medicago denticulata Willd.	Burr medic	*H. armigera*
Medicago sativa L.	Lucerne	*H. punctigera*
Phaseolus vulgaris L.	French bean	*H. armigera*
Pisum sativum L.	Garden pea	*H. armigera*
		H. punctigera
Trifolium repens L.	White clover	*H. punctigera*
Linaceae		
Linum usitatissimum L.	Linseed	*H. armigera*
		H. punctigera
Malvaceae		
Gossypium hirsutum L.	Cotton	*H. armigera*
		H. punctigera
Hibiscus esculentus L.	Okra	*H. armigera*
Musaceae		
Musa acuminata Colla	Cavendish banana	*H. armigera*
Rosaceae		
Fragaria × *ananassa* Duchesne	Strawberry	*H. armigera*
		H. punctigera

(b) Hosts—Heliothis species—*continued*

Botanical Name	Common Name	Species Recorded
Rutaceae		
Citrus sinensis Osbeck ..	Orange	*H. armigera*
Solanaceae		
Lycopersicon esculentum Mill.	Tomato	*H. armigera*
		H. assulta
		H. punctigera
Nicotiana tabacum L.	Tobacco	*H. armigera*
		H. punctigera
Physalis minima L.	Wild gooseberry	*H. assulta*
Physalis peruviana L.	Cape gooseberry	*H. assulta*
Vitaceae		
Vitis vinifera L.	Grape	*H. armigera*

V. COMMENTS

The seasonal incidence of all species is similar, adults and larvae occurring mainly during the warmer months (September–April), with little activity during winter. Developing reproductive parts of hosts are most attractive as food, but buds and young leaves may be eaten during periods of insect abundance and scarcity of preferred food.

Differences in pest status among species are considerable. *H. armigera, H. punctigera* and *H. assulta* only are recorded from economically important hosts, *H. assulta* having the most restricted host range.

Almost all Heliothis damage in crops except cape gooseberry in coastal and subcoastal Queensland is caused by either *H. armigera* or *H. punctigera* or both, as mixed populations of larvae are common. In inland areas, only *H. punctigera* seems to be involved in attacks on crops. The most significant damage caused by these two species is in linseed, tobacco and tomatoes, and control measures are often necessary to prevent serious losses. Satisfactory chemical controls have been evolved over the years (see, for example, Passlow, Hooper, and Rossiter 1960; Smith 1961), and there is no evidence that the presence of the two species has ever been a factor in control. In the other hosts listed for these species, controls are warranted only occasionally, and methods proved on the more important crops would apply.

Economic damage by *H. assulta* is normally confined to cape gooseberry, and in the absence of satisfactory controls this species has been a limiting factor in the production of the crop during the warmer months for many years. It appears (unpublished data, Queensland Department of Agriculture and Stock) that controls effective against the other species are ineffective against *H. assulta;*

this may be due to either the protection afforded the larvae by the "cape" or a difference in susceptibility to insecticides. Overseas, this species is known as a pest of tobacco (Van der Laan 1940) but attacks in this crop have not been recorded from Queensland.

VI. ACKNOWLEDGEMENTS

Departmental officers, particularly entomologists, throughout the State have assisted in the collection of adult and larval *Heliothis* specimens from crops in their districts. The staff of the Botany Section has identified botanical specimens and checked the lists for publication. All this assistance is gratefully acknowledged.

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STUDIES OF PLANT AND SOIL NEMATODES

4. *TYLENCHULUS OBSCURUS* N.SP. (NEMATODA: TYLENCHULIDAE)

By R. C. Colbran, M.Agr.Sc.*

SUMMARY

Tylenchulus obscurus **is described from the roots of** *Hodgkinsonia frutescens* **C. T. White. This species is closely related to** *T. mangenoti* **Luc but can be distinguished by the pre-equatorial position of the excretory pore.**

I. INTRODUCTION

Two species of the genus *Tylenchulus* have been described previously. *T. semi-penetrans* Cobb (the citrus nematode) is an important pest in most countries where citrus is grown; *T. mangenoti* Luc is a root parasite of *Dorstenia embergeri* G. Mangenot in Ivory Coast.

Recently larvae of a new species of *Tylenchulus* were obtained from soil associated with the roots of *Hodgkinsonia frutescens* C. T. White, a shrub common on rain-forest margins in North Queensland. The swollen, tightly coiled females of the species were subsequently found in young roots in which they were partially embedded under the cover of small, dark, brittle scales. Usually one female, sometimes two, occurred under a scale, together with numerous eggs and larvae and an occasional male. Females were obtained by staining small pieces of infested root in cotton blue lactophenol and pressing them between glass slides.

II. DESCRIPTION

Tylenchulus obscurus n.sp.

(Figures 1 and 2)

Females.—L = 264-333μ; a =4·5-5·8; b = 2·5-3·9; c = 11·0-13·3; V = 77-78%; P.E. = 46%.

Holotype.—L = 280μ; a = 5·8; b = 3·9; c = 11·2; V = 77%; P.E. = 46%.

Body short, tightly coiled, middle greatly enlarged, tapering towards both ends. Head hemispherical; internal sclerotization weak. Cuticle with fine transverse striae 3·5μ apart in mid-body region on dorsal side. Stylet 12μ long; basal

* Research Entomologist, Queensland Department of Agriculture and Stock.

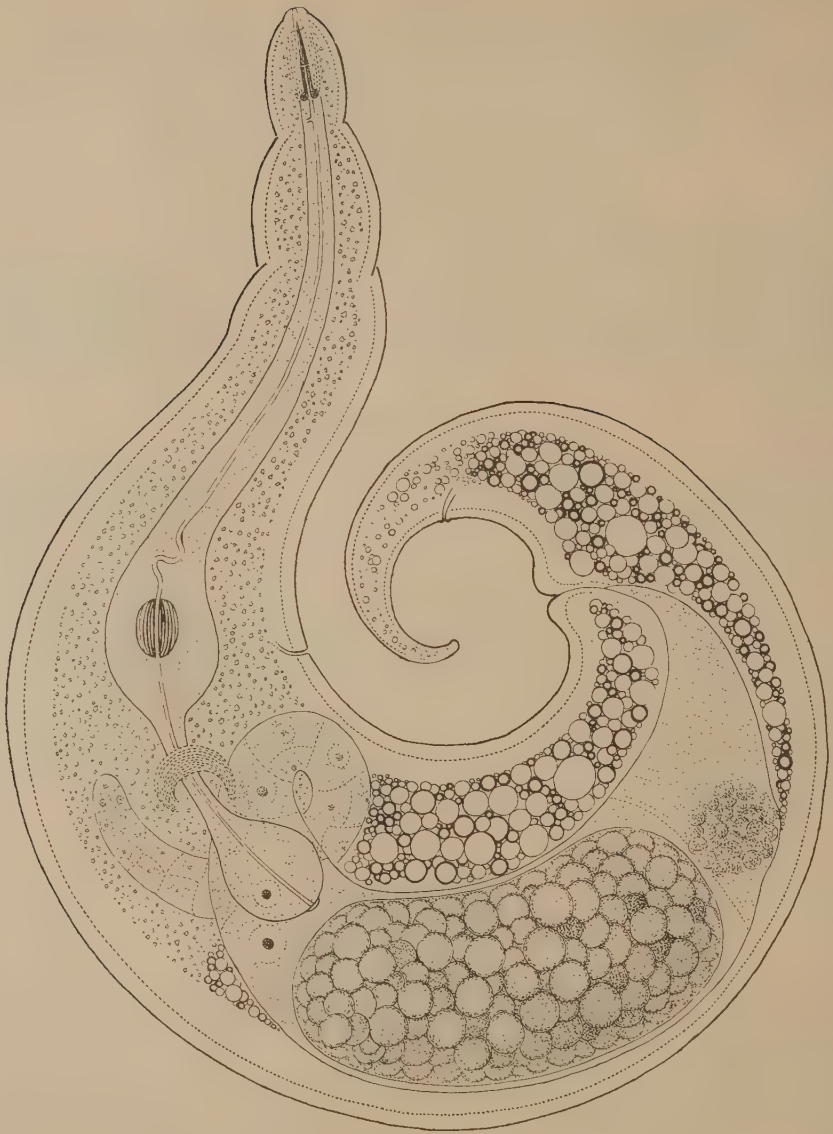

Fig. 1.—*Tylenchulus obscurus n.sp.* Mature female (× 1000).

knobs small, rounded, 2μ across. Dorsal oesophageal gland orifice 5μ behind stylet. Prorhabdion half stylet length. Oesophagus with large, ovate metacorpus 16·7μ wide containing sclerotized crescentic valve 7μ long; isthmus slender,

22μ long; terminal bulb pyriform, smaller than metacorpus. Nerve ring crossing isthmus immediately behind metacorpus. Excretory pore pre-equatorial; canal directed anteriorly. Vulval lips enlarged. Ovary single, prodelphic, coiled. One egg at a time in uterus. Post-vulval uterine sac absent. Tail short, conoid-arcuate; terminus bluntly rounded.

Males.—L = 319-417μ; a = 26-31; b = 3·6-3·8; c = 7·1-7·7; T = 36-42%; P.E. = 38%.

Allotype.—L = 389μ; a = 30·4; b = 3·6; c = 7·4; T = 38%; P.E. = 38%.

Body slender, vermiform. Cuticle with fine transverse striae 0·6μ apart in mid-body region. Head hemispherical, not offset; internal sclerotization weak. Stylet 9μ long, apparently non-functional; small median and terminal swellings present. Oesophagus partially degenerate. Procorpus long, slender; metacorpus ovate, one-third as wide as body, valve absent; isthmus long, subequal in width with procorpus; terminal bulb rudimentary. Hemizonid one mid-body diameter behind metacorpus. Nerve ring crossing isthmus midway between metacorpus and hemizonid. Excretory pore pre-equatorial, 2·8 mid-body diameters behind oesophagus; canal directed posteriorly. Anus surrounded by slight body elevation. Caudal alae absent. Spicules slightly arcuate, 11μ long. Gubernaculum narrow, arcuate, 3·5μ long. Tail conoid, 5 anal body diameters long; terminus bluntly rounded.

Larvae (*second stage*).—L = 250-300μ; a = 24-27; b = 2·8-3.4; c = 9·0-9·4; P.E. = 42-45%.

Body slender, vermiform, straight when relaxed. Cuticle with fine transverse striae 0·6μ apart in mid-body region. Lateral fields with 4 incisures. Head hemispherical, not offset. Stylet 14-15μ long; knobs 1·6μ across, rounded. Prorhabdion about half stylet length. Dorsal oesophageal gland orifice 4-5μ behind stylet. Procorpus gradually widening to ovate metacorpus with sclerotized valve 4μ long; isthmus about half as wide as procorpus, 2·5 mid-body widths in length; terminal bulb pyriform, twice as long as wide. Conoid oesophago-intestinal valve present. Nerve ring crossing middle of isthmus. Hemizonid slightly posterior to nerve ring. Excretory pore 2-3 mid-body widths behind oesophagus; canal directed posteriorly. Tail conoid, 5-6 times as long as anal body width; terminus bluntly rounded.

Eggs.—62-70μ x 25-30μ.

Types.—Holotype (female) slide Reg. No. G2517 and allotype (male) slide Reg. No. G2518 in the Queensland Museum; labelled paratypes preserved in F.A.A. in the Queensland Department of Agriculture and Stock Nematology Collection.

Fig. 2.—*Tylenchulus obscurus* n.sp. Left, male (× 500); right, larva (second stage) (× 500).

Type host.—*Hodgkinsonia frutescens* C. T. White.

Type locality.—Rain-forest near Tolga, North Queensland.

Diagnosis.—In *T. obscurus* as in *T. mangenoti* (Luc 1957) an exudate from the mature female hardens to form a protective scale-like cover; in *T. semi-penetrans* the exudate remains soft and sand grains readily adhere to it. Larvae of *T. obscurus* and *T. mangenoti* have shorter, more robust tails than larvae of *T. semi-penetrans.* In females, males and larvae of *T. obscurus* the excretory pore is pre-equatorial in position; in *T. mangenoti* the pore is equatorial or post-equatorial.

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EFFECT OF GRAZING MANAGEMENT ON AN IRRIGATED PASTURE IN SOUTH-EASTERN QUEENSLAND

By C. A. Schroder*

SUMMARY

Various grazing treatments were applied to an irrigated pasture of phalaris, cocksfoot, H1 ryegrass and Irrigation white clover over a period of three years.

Pasture green-weight yields decreased in all treatments. The decrease was greater in treatments with set uniform resting periods than in treatments in which the resting period varied in length. With set uniform resting periods pasture yields fell with frequency of grazing.

Pasture carrying capacity decreased in all treatments. The decrease was greater in treatments with set uniform resting periods than in treatments in which the resting period varied in length. With set uniform resting periods the decrease did not follow the same pattern as that exhibited by pasture green-weight yields.

Serious invasion by foreign species occurred in treatments with set resting periods of 30 days or less. White clover declined in all treatments.

Unevenness in pasture cover quickly developed in treatments grazed every 30 days or more frequently. Treatments that provided a long resting period in late summer and autumn maintained a satisfactory cover.

I. INTRODUCTION

The Queensland Bureau of Investigation of Land and Water Resources opened an Irrigation Research Station at Gatton, in the Lockyer Valley, in 1946. This Station was taken over by the Department of Agriculture and Stock in 1957 and designated the Gatton Regional Experiment Station.

Since the inception of the Station, the emphasis has been on investigations of irrigated pastures. The trial reported here was designed to examine the effects of a number of grazing treatments with dairy cattle on the production, carrying capacity, botanical composition and evenness of cover of a permanent irrigated pasture of temperate grasses and white clover. The trial was carried out from July 1, 1954, to June 30, 1957.

II. MATERIALS AND METHODS

The soil in the trial area was a deep alluvial clay loam of good structure and high inherent fertility. Because of its satisfactory plant food status, fertilizers are not used on this soil type and none was applied to this trial.

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The pasture had been planted 15 months prior to the commencement of the trial and was well developed and vigorous. The species consisted of phalaris (*Phalaris tuberosa*), cocksfoot, H1 ryegrass and Irrigation white clover.

The area available for the trial totalled 4·8 ac and for the purposes of the trial it was subdivided into plots of 0·6 ac to provide for eight treatments. This plot size was considered to be the minimum which would permit the planned grazing management schedules to be satisfactorily applied so as to simulate conditions under normal farming practice with dairy stock. Replication of treatments, by reducing plot size, would have introduced undesirable practical conditions and was therefore not adopted.

When grazing of this type of pasture was first commenced at the Station, only four areas were available and the method adopted was one week's grazing followed by three weeks' rest. A pasture pattern (unevenness of the cover)

Table 1

DETAILS OF TREATMENTS

Treatment	Resting Period (days)	Flexibility in Resting Period (days)*	Grazing Period (days)†	Grazing Management Adopted
A	15	±2	5 days	Overgrazing practice
B	15	± 2	„ „	Good grazing practice
C	20	± 5	„ „	„
D	30	± 5	„ „	„
E	40	± 5	„ „	„
F	Summer 20	± 2	„ „	„
	Winter 50	± 5		
G	30	± 5	Average stocking intensity. If more than 5 days' grazing were available a back fence was used after that time to prevent grazing of regrowth	„
	Rested (grazing deferred) March, April, May, grazed June	± 15		
H	30	± 5	„	„
	Rested April, May, June, grazed July	± 15		

* Some flexibility in the resting period was provided to allow easier handling of grazing in unfavourable weather conditions or when grazing of a number of treatments coincided.

† Where the grazing period was fixed at five days, the number of stock used was adjusted accordingly. By April 1955 little grazing was available in some treatments and the length of the grazing period was therefore reduced to suit the circumstances.

quickly developed and grazing efficiency, plant vigour and pasture production decreased; in the period of slow growth in autumn and winter the depreciation rate was serious. When additional areas became available for grazing it was found that allowing the pasture sufficient rest to achieve good growth before grazing resulted in much less depreciation than formerly. The length of spell required increased as weather conditions for pasture growth deteriorated. In working out the grazing treatments to be examined in the trial it was considered desirable to use resting periods of set lengths rather than to graze at various stages of pasture development, as these stages could not be determined with sufficient precision.

Previous experience had indicated that resting periods that did not permit sufficient development of pasture between grazings could cause rapid and serious deterioration. It was considered that a trial period of three years would provide sufficient information on the effects of the treatments to be employed.

The treatments used were as shown in Table 1.

Following each grazing period, manure on the pasture was spread with a "Dillon" pasture harrow, care being taken to avoid any cultivation effect or any damage to the pasture components.

Pasture yield was assessed by quadrat cuts (51·3 in. x 24 in.) at the rate of one per bay (5 per acre).

Botanical composition was measured by hand sorting of representative samples derived from the bulked quadrat material.

Evenness of cover was assessed on August 28, 1956, and July 1, 1957, on a scale ranging from 0 (evenly mixed pasture cover of uniform growth) to 10 (pasture cover most uneven).

A record was kept of cow-grazing-days.

The stock used were six Jersey cows and six Australian Illawarra Shorthorn cows, all in milk.

Surface irrigation was applied to provide maximum pasture production. It was timed to fit in with the grazing schedule. Details of irrigation and rainfall are shown in Table 2.

Table 2

IRRIGATION AND RAINFALL

Month	1.vii.54–30.vi.55								
	Irrigation applied in inches								Rainfall
	A	B	C	D	E	F	G	H	
July ..	..	..	..	..	..	..	..	..	5·56
Aug. ..	..	..	..	..	..	..	..	..	2·77
Sept. ..	3·9	3·9	3·9	6·3	2·4	2·4	2·4	2·4	2·25
Oct. ..	2·2	2·2	2·2	2·2	2·6	2·6	2·6	2·6	4·99
Nov. ..	2·4	2·4	2·4	2·4	..	..	..	..	3·32
Dec. ..	..	4·2	5·1	3·0	9·5	8·8	8·8	8·8	2·71
Jan. ..	2·4	2·4	5·5	5·5	5·8	5·8	..	5·8	5·24
Feb. ..	..	..	..	..	3·8	3·8	3·8	3·8	2·21
March ..	4·3	4·3	5·2	6·0	6·1	6·1	6·1	3·4	10·00
April ..	5·0	5·0	5·0	5·0	4·8	4·8	2·2	2·4	5·25
May ..	2·5	2·5	2·5	..	2·7	..	..	..	4·14
June ..	2·5	2·5	2·5	2·5	2·4	2·4	2·4	2·4	·82
Total ..	25·2	29·4	34·3	32·9	40·1	36·7	28·3	31·6	49·26

IRRIGATION AND RAINFALL—*continued*

Month	1.vii.55–30.vi.56								
	Irrigation applied in inches								Rainfall
	A	B	C	D	E	F	G	H	
July ..	1·7	1·7	1·7	1·7	2·4	2·4	2·4	2·4	1·91
Aug. ..	3·6	3·6	3·6	5·2	4·9	4·9	4·4	5·2	·48
Sept. ..	5·6	5·6	5·6	5·6	5·9	5·9	5·9	5·9	2·59
Oct. ..	4·5	4·5	4·5	4·5	6·2	6·2	6·2	6·2	3·08
Nov. ..	4·7	4·7	4·7	4·7	5·3	5·3	5·3	5·3	·97
Dec. ..	3·5	3·5	3·5	6·8	5·5	2·9	2·9	5·2	4·10
Jan. ..	9·0	6·1	6·1	6·7	8·9	8·9	8·9	8·6	3·91
Feb. ..	..	..	..	..	..	..	..	..	11·05
March ..	..	..	..	..	..	..	..	..	3·86
April ..	3·0	3·0	3·0	3·0	3·3	3·3	3·3	3·3	4·94
May ..	2·5	2·5	2·4	2·4	2·2	2·2	2·2	2·2	4·57
June ..	2·4	2·4	2·4	3·8	2·8	2·8	2·8	2·8	3·01
Total ..	40·5	37·6	37·5	44·4	47·4	44·8	44·3	47·1	44·47

IRRIGATION AND RAINFALL—*continued*

Month	1.vii.56–30.vi.57								
	Irrigation applied in inches								Rainfall
	A	B	C	D	E	F	G	H	
July ..	..	..	..	..	..	..	..	..	1·01
Aug. ..	5·8	5·8	5·8	5·8	4·4	4·4	4·4	4·4	·06
Sept. ..	3·0	3·0	3·0	3·0	6·9	6·5	6·5	6·9	·14
Oct. ..	7·1	7·1	7·1	7·1	8·6	8·6	7·7	8·6	·78
Nov. ..	6·4	6·4	6·4	8·0	10·2	10·2	10·9	10·2	·35
Dec. ..	..	3·5	3·5	3·5	3·0	3·0	3·0	..	8·39
Jan. ..	5·6	5·6	5·6	5·6	7·0	7·0	7·0	7·0	1·99
Feb. ..	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	2·70
March ..	3·7	3·7	4·0	4·0	4·5	4·5	4·5	4·5	2·84
April ..	6·9	6·9	6·9	4·9	8·9	8·9	8·9	8·9	·67
May ..	6·9	6·9	6·9	4·8	5·9	5·9	5·9	5·9	..
June ..	2·6	2·6	2·6	2·6	2·4	2·4	2·4	2·4	·85
Total ..	56·4	59·9	60·2	57·7	70·2	69·8	65·6	67·2	19·78

Application rates are all calculated from the amounts actually pumped and have no regard for losses by seepage from head ditches or run-off from bays from excessive application.

III. RESULTS

(a) Pasture Yields

Green yields were recorded at each time of grazing. These provide a comparison of annual yields and growth rates within treatments and show the effect of treatment over three years.

The pasture green yields are shown in Table 3 and Figure 1. Production was high in all treatments in the first year, but declined in the second year in all treatments. The decline ranged from 1·2 per cent. in Treatment B to 17·5 per cent. in Treatment E. The mean annual production in the second year for all treatments was 11·1 per cent. less than in the first year.

The decrease was accelerated in practically every treatment in the third year, and as a result the mean annual production for all treatments was 22·0 per cent. less than in the second year. Only Treatment H failed to show a decline.

The average reduction in pasture green yields for all treatments from first year to third year was 30·6 per cent. The reduction in Treatments A, B and C was serious at 39 per cent., 41 per cent., and 40 per cent. respectively. Treatment H showed the small decline of only 5 per cent.

Treatments providing set uniform resting periods throughout the year (A, B, C, D, E) showed greater decline in production than treatments where the length of spelling varied (F, G, H). The mean reduction for the two groups was 37·4 per cent. and 19·1 per cent. respectively.

Table 3

PASTURE GREEN YIELDS

Treatment	1.vii.54–30.vi.55		1.vii.55–30.vi.56		1.vii.56–30.vi.57		Means		Reduction in Yield, 1st Year to 3rd Year
	Total Green Yield (tons/ac)	Average Weekly Growth Rate (tons/ac)	Total Green Yield (tons/ac)	Average Weekly Growth Rate (tons/ac)	Total Green Yield (tons/ac)	Average Weekly Growth Rate (tons/ac)	Total Green Yield (tons/ac)	Weekly Growth Rate (tons/ac)	(%)
A	45·09	·86	42·52	·81	27·44	·53	38·35	·73	39·1
B	44·34	·85	43·80	·83	25·97	·50	38·04	·73	41·4
C	45·43	·87	38·08	·73	27·10	·52	36·87	·71	40·3
D	46·70	·89	42·19	·81	29·15	·55	39·35	·75	37·6
E	42·01	·81	34·66	·66	30·22	·58	35·63	·68	28·1
F	45·00	·86	37·70	·72	33·00	·63	38·57	·74	26·7
G	44·37	·85	41·21	·79	33·17	·64	39·58	·76	25·2
H	43·62	·84	36·94	·71	41·41	·79	40·66	·78	5·1
Mean ..	44·57	·85	39·64	·76	30·93	·59	38·38	·73	30·4

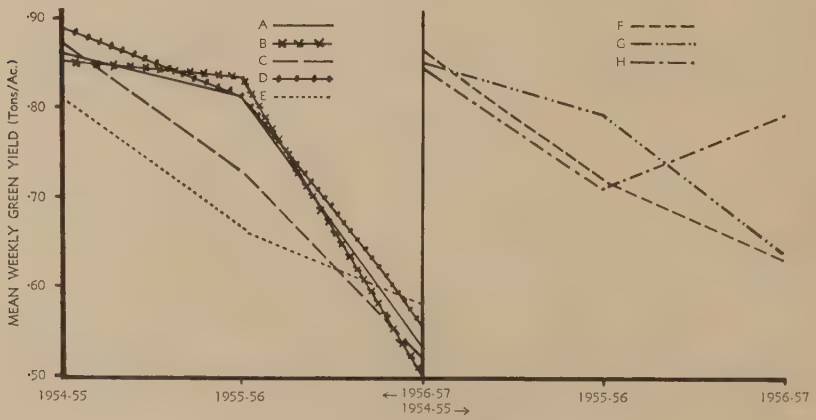

Fig. 1.—Mean weekly green weight yield of pasture.

In treatments giving set uniform spells, production fell with frequency of grazing.

As it may be assumed that the moisture content of the pasture was higher in treatments with short resting periods than in those with long spells, it is evident that Treatments H and G maintained better production rates than A, B, C, D and F, while E cannot be compared.

The only treatment in which there was any apparent loss of quality or attractiveness to stock was Treatment E, in which cocksfoot was not well accepted in late spring and summer, and an ungrazed residue remained when stock were removed.

(b) Carrying Capacity

Grazing data, expressed as full-time days of grazing, are given in Table 4 and Figure 2.

Table 4

PASTURE GRAZING YIELDS

Treatment	1.vii.54–30.vi.55		1.vii.55–30.vi.56		1.vii.56–30.vi.57		Means		Reduction in Grazing Yield 1st Year to 3rd Year (%)
	Total Cow Days	Carrying Rate/Acre	Total Cow Days	Carrying Rate/Acre	Total Cow Days	Carrying Rate/Acre	Cow Days	Carrying Rate/Acre	
A	549	2·51	450	2·05	202	·92	400·3	1·83	63·2
B	453	2·07	414	1·89	183·5	·84	350·2	1·60	59·5
C	510	2·33	400	1·82	285	1·30	398·3	1·82	44·1
D	456	2·08	435	1·98	253·5	1·16	381·5	1·74	44·4
E	456	2·08	399·4	1·82	210·4	·96	355·3	1·62	53·9
F	405	1·85	400	1·82	292·5	1·34	365·8	1·67	27·8
G	410	1·87	450	2·05	291	1·33	383·7	1·75	29·0
H	454	2·07	420	1·91	331	1·51	401·7	1·83	27·1
Mean ..	461·6	2·11	421·0	1·92	256·1	1·17	379·6	1·73	43·6

Grazing yield is expressed as full-time cow-days of grazing per plot.

Calculated carrying rate is expressed as number of cows carried per acre (365 cow-days per acre per annum = 1 cow per acre).

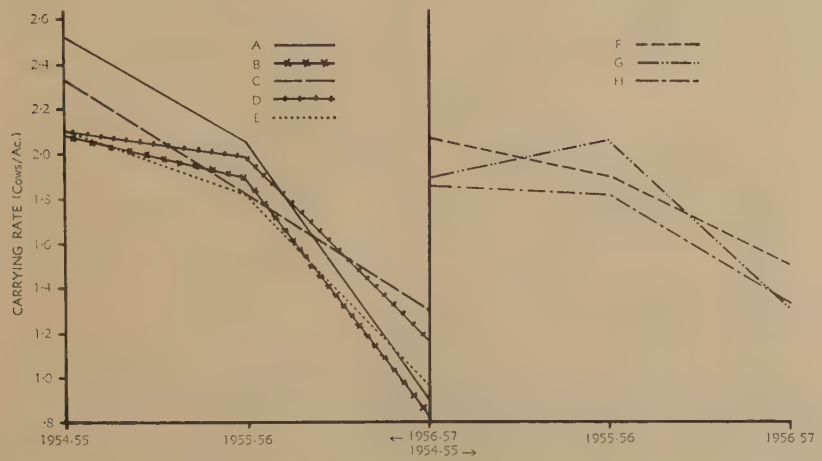

Fig. 2.—Carrying rate of pasture.

Due to pasture depreciation there were times when no grazing was available at the scheduled dates in some treatments. In 1956, there was no grazing available in Treatments A, B and C between July 24 and September 12. In 1957, Treatments A and B could not be grazed between May 21 and July 11, and

Treatments C and D between May 5 and July 12 and May 27 and July 12 respectively. For this year, pasture growth and grazing were allotted to June 30 on a *pro rata* basis from figures determined at subsequent grazings.

It is evident from the data that the overall grazing return declined from year to year. The decline in the second year (mean reduction for all treatments 8·8 per cent.) was not great, but the mean return dropped sharply in the third year, when it was 39·2 per cent. less than in the second year.

The average reduction in pasture grazing yields for all treatments from first year to third year was 43·6 per cent.

Treatments providing set uniform resting periods throughout the year (A, B, C, D, E) showed greater decline in grazing yield than treatments where the length of spelling varied (F, G, H). The mean reduction for the groups was 53·2 per cent. and 27·9 per cent. respectively.

Decrease in grazing yields did not follow the same pattern as decrease in pasture yields. The percentage decrease in grazing yields was greater than the percentage decrease in pasture yields. The average decline in the grazing yield from the first year to the third year was 43·6 per cent., while the corresponding decline in pasture yield was 30·4 per cent. This resulted from reduced grazing efficiency caused by the severity of the grazing pattern aggravated by unpalatability (poor acceptance by stock) in late spring and summer of cocksfoot in Treatment E and invaders in Treatment D.

(c) Botanical Composition

A summary of the analyses of botanical composition is given in Table 5.

Figures 3–5, based on the data in Table 5, show the effects of various treatments on the botanical composition.

The percentage of sown grasses increased in the first half of the trial and declined thereafter.

It will be noted that the amount of grass and its proportion to white clover were particularly high in Treatment E, the treatment with the longest set uniform resting period and the least number of grazings per year. This was due to the neglect by stock during late spring and summer of cocksfoot, which developed big stools, and for this reason was able to persist well and to control invaders, at the same time overlaying and reducing the white clover.

Invasion by foreign species was high in Treatments A, B, C and D. The plants mainly involved were paspalum (*Paspalum dilatatum*), nut-grass (*Cyperus rotundus*) and wild millet (*Echinochloa crus-galli*). Their development was favoured in summer in the selectively overgrazed areas.

Table 5

BOTANICAL COMPOSITION*

Treatment	Year	Botanical Composition		
		Sown Species		Invading Species
		White Clover (%)	Grasses (%)	(%)
A	1954–55	63·9	18·5	17·7
	1955–56	56·1	19·0	24·9
	1956–57	41·3	12·5	46·2
B	1954–55	67·3	13·9	18·8
	1955–56	53·2	21·1	25·7
	1956–57	41·3	14·8	43·9
C	1954–55	72·9	14·0	13·1
	1955–56	50·9	21·6	27·5
	1956–57	38·5	12·8	48·7
D	1954–55	68·6	15·7	15·7
	1955–56	50·8	23·9	25·3
	1956–57	37·1	9·0	53·9
E	1954–55	60·3	32·6	7·1
	1955–56	41·2	48·8	10·0
	1956–57	35·8	44·4	19·8
F	1954–55	63·1	27·6	9·2
	1955–56	53·5	29·2	17·3
	1956–57	58·9	14·5	26·6
G	1954–55	61·9	32·1	6·0
	1955–56	49·5	38·2	12·3
	1956–57	49·7	20·1	30·2
H	1954–55	55·7	30·7	13·6
	1955–56	44·4	47·7	7·9
	1956–57	51·6	35·5	13·1

* Average annual composition derived from individual analyses at grazing periods.

The grasses persisted quite well in Treatments H and G and exercised some control over the invasion of paspalum and nut-grass. Grazing regularly until the end of March and then deferring grazing for three months (Treatment H) gave better control of invaders than where deferment was commenced at the end of February (Treatment G).

In Treatments A, B, C, D and F the decline of the sown grasses was very serious and the individual plants had become small and lost most of their vigour at the end of the trial.

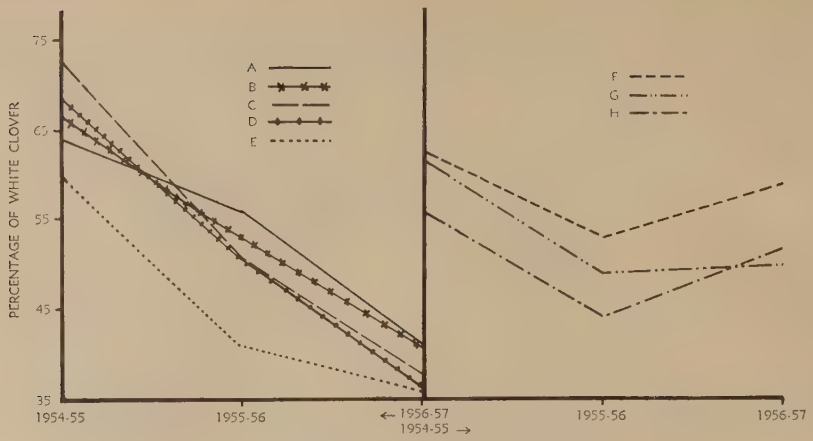

Fig. 3.—White clover content of pasture.

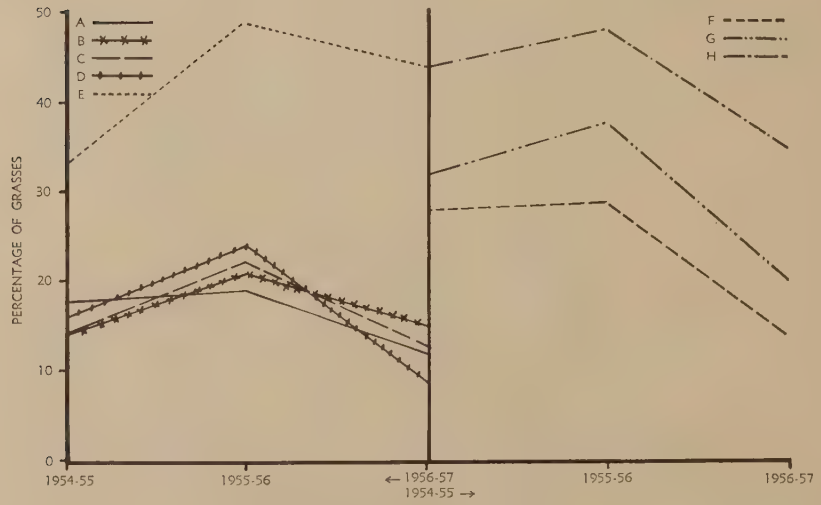

Fig. 4.—Grass content of pasture.

White clover declined in all treatments, and in all except F, G and H had declined to such extent as to provide very little grazing.

At the end of the trial the pastures in Treatments A, B, C, D and F had lost their identity as mixtures of temperate species and were virtually mixtures of summer grasses and white clover.

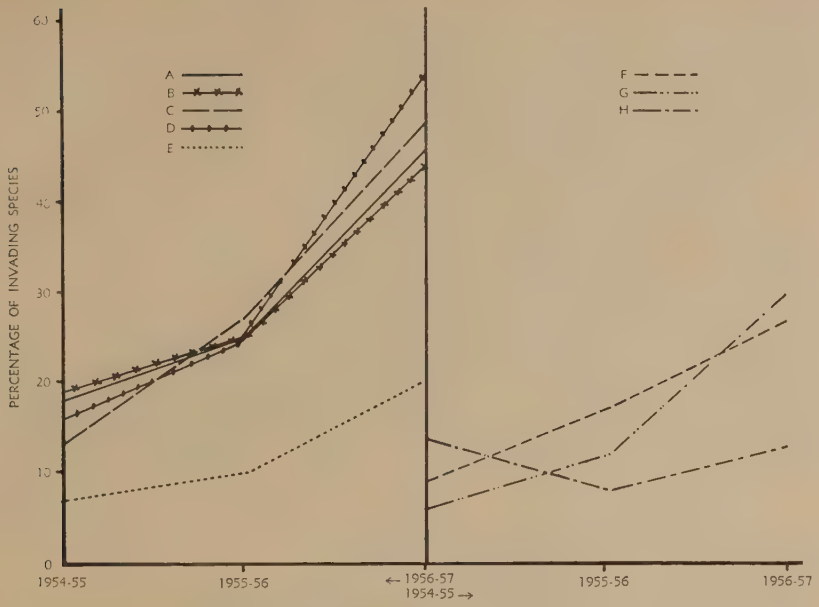

Fig. 5.—Invading species content of pasture.

(d) Evenness of Cover

The ratings for evenness of cover on the recording dates were as follows:—

Treatment	28.viii.56	1.vii.57
A	10	10
B	9·5	10
C	9	10
D	8	10
E	7	7
F	5	5
G	4	4
H	3	3

In some of the treatments, as a result of the grazing habits of stock, marked pattern effects were evident before the end of the first year and had become very pronounced by the end of the second year. At the conclusion of the trial,

Treatments A, B, C and D had a most uneven pasture cover and the pasture had reached a condition where it could no longer be maintained in first-class condition. At the same time, the treatments that provided a long rest in late summer/autumn, and 30-day spells during the rest of the year (H and G), maintained a satisfactory evenness of cover.

IV. DISCUSSION

In all the treatments in which the resting period was uniform throughout the year, pasture deterioration was serious. This was shown by slower growth rate of the pasture, lower stock carrying capacity, and deterioration of the botanical composition. Selective grazing quickly developed. Some of the effects of this were unevenness in the pasture cover, overgrazing of selected patches, reduction of vigour and low production of various species, heavy invasion by volunteer species, and a drop in annual production. Invasion was particularly heavy in treatments in which the resting period was 15, 20 or 30 days.

The treatment which provided for resting periods of 20 days in summer and 50 days in winter resulted in less depreciation than those providing uniform lengths of spell.

A long resting period before winter was of great benefit to the pasture. It did much to remedy selective grazing and to increase the vigour of weakened plants—the best treatment was that in which the pasture was ungrazed in April, May and June.

The trial indicates that maintenance of even pasture cover at all times is of paramount importance, and that the pasture cover is a good indication of the efficiency of the grazing practices employed.

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FIELD OBSERVATIONS ON THE DAILY MILK INTAKE OF MERINO LAMBS IN SEMI-ARID TROPICAL QUEENSLAND

By G. R. Moule, D.V.Sc.* and R. B. Young †

SUMMARY

The milk intakes of lambs were measured over 15 hours each day when the ewes grazed indigenous pasture, or were fed various rations, at Longreach in central-western Queensland. The results indicated that the milk production of Merino ewes can be influenced by nutrition before and after lambing, and that large variations occur in the lamb's milk intake, both daily and at different times of the day.

I. INTRODUCTION

The short growing period characteristic of pasture in semi-arid areas produces marked fluctuations in the amount and quality of the forage available to sheep and it was considered that this may influence milk production. The work described in this paper was commenced in 1950 with an attempt to measure milk production of ewes grazing indigenous pasture in the Longreach district in central-western Queensland. However, because low stocking rates characteristic of pastoral conditions made it difficult to determine milk production, the ewes in subsequent observations conducted in 1951 and 1952 were confined and fed a standard ration. In addition, an experiment was conducted in 1952 when the ewes were fed rations chosen to make their liveweight changes simulate those often recorded under field conditions in a semi-arid environment.

II. MATERIALS AND METHODS

Peppin strain Merino ewes between 3 and 5 years old were used in these observations, which were made between September and November in 1950, 1951 and 1952.

The ewes lambed under surveillance and were then brought to the sheep yards. When the lambs were about 24 hours old they were separated from their mothers from 6.0 a.m. to 9.0 p.m. each day. Because of the high temperatures and aridity of the air, the lambs were allowed to suck every 3 hours, i.e.

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at 9.0 a.m., 12 noon, 3.0 p.m., 6.0 p.m. and 9.0 p.m., and they were weighed before and after sucking. For the purpose of this paper the term "daily milk intake" is used to describe that measured between 6.0 a.m. and 9.0. p.m.

The lambs were weighed on a clockface scale graduated in ounces. The ewes were weighed on a clockface scale graduated in ½ lb.

Ewes that bore single lambs were used in the experiments and the ewes and lambs were identified by numbered ear-tags. In 1950 the ewes were allowed free grazing between sucking periods and at night, and were not offered any supplementary food. During observations in 1951 and 1952, the ewes were confined in yards after lambing and except when the rations were deliberately changed were fed each day on lucerne hay and compressed "nuts" in quantities calculated to provide 3·75 lb digestible crude protein (D.C.P.) and 10 lb starch equivalent (S.E.) per head per week.

In the experiment where the rations were varied, which was also conducted in 1952, 24 ewes were stratified according to their age and liveweight after lambing, and were then allotted at random to one of four groups. The liveweight of each ewe was recorded once a week for the duration of the experiment and the ewes were fed on lucerne hay and concentrates, estimated to provide the following nutritional regimens:

High-High 3.0 lb D.C.P. and 12·0 lb S.E. per week for 6 weeks.

High-Low 3·0 lb D.C.P. and 12·0 lb S.E. per week for first 3 weeks and 1·2 lb D.C.P. and 5·0 lb S.E. for next 3 weeks.

Low-High 1·2 lb D.C.P. and 5·0 lb S.E. per week for first 3 weeks and 3·0 lb D.C.P. and 12·0 lb S.E. for next 3 weeks.

Low-Low 1·2 lb D.C.P. and 5·0 lb S.E. per week for 6 weeks.

The bodily condition of the ewes varied owing to the different seasonal conditions that prevailed in each year. In 1950, "effective rain", based on a rainfall/evaporation ratio of 0·3 (Farmer, Everist, and Moule 1947), fell during the two months preceding mating and during the 3rd, 4th and 5th months of gestation. In consequence, there was an abundance of green feed at and following lambing and the ewes were in good bodily condition.

In 1951, "effective rain" fell during the month preceding mating, but there was no rain during either the gestation or the lambing. As a result, the only forage available was dry and the ewes were in poor condition.

In 1952, "effective rain" fell during the month preceding mating and during the second month of gestation, and although the feed was dry the ewes, which were lean at lambing time, were quite strong.

III. RESULTS

(a) Milk Intake at Different Times of the Day

In each year the general patterns of milk intake for the 21-day period beginning the day after birth were similar. The midday intake, which was the lowest in each year, was significantly less than the maximum intake at 9.0 p.m. Mean intakes at different times of the day for 1952 are shown in Table 1.

TABLE 1

MEAN MILK INTAKES OF 4 SINGLE LAMBS AT VARIOUS TIMES OF THE DAY—1952

Time	Milk Intake (oz)	Remarks
9.0 a.m.	5·0	9.0 p.m. higher than noon ($P < 0.001$)
12 noon	4·3	9.0 p.m. higher than 6.0 p.m. ($P < 0.01$)
3.0 p.m.	4·9	9.0 a.m. and 3.0 p.m. higher than noon ($P < 0.05$)
6.0 p.m.	4·4	
9.0 p.m.	5·5	

(b) Milk Intake During the First Few Weeks

In all observations milk intakes followed similar trends during the first two weeks, rising rapidly to reach an early peak, and then declining, as shown in Figure 1. In each year large daily fluctuations occurred in measured intake; there were also substantial differences between the total intakes measured in each year.

(c) Liveweight Changes During the Day

The mean changes in liveweight of the lambs during the day for the first 20 days of life in the observations in 1951 and 1952 are shown in Table 2. These are based on the weights of the lambs before each sucking period.

TABLE 2

MEAN CHANGES IN LIVEWEIGHT OF LAMBS AT DIFFERENT PERIODS OF THE DAY DURING THE FIRST 20 DAYS OF LIFE—1951 AND 1952

Time	Net Increase in Liveweight (oz)	
	1951 5 lambs	1952 4 lambs
6.0—9.0 a.m.	−1·5	−2·3
9.0—12 noon	+0·5	+2·0
Noon—3.0 p.m.	−0·7	−0·5
3.0—6.0 p.m.	+0·1	+0·2
6.0—9.0 p.m.	+0·7	−0·4
Overnight	+9·0	+9·0
Total daily gain	+8·0	+8·0

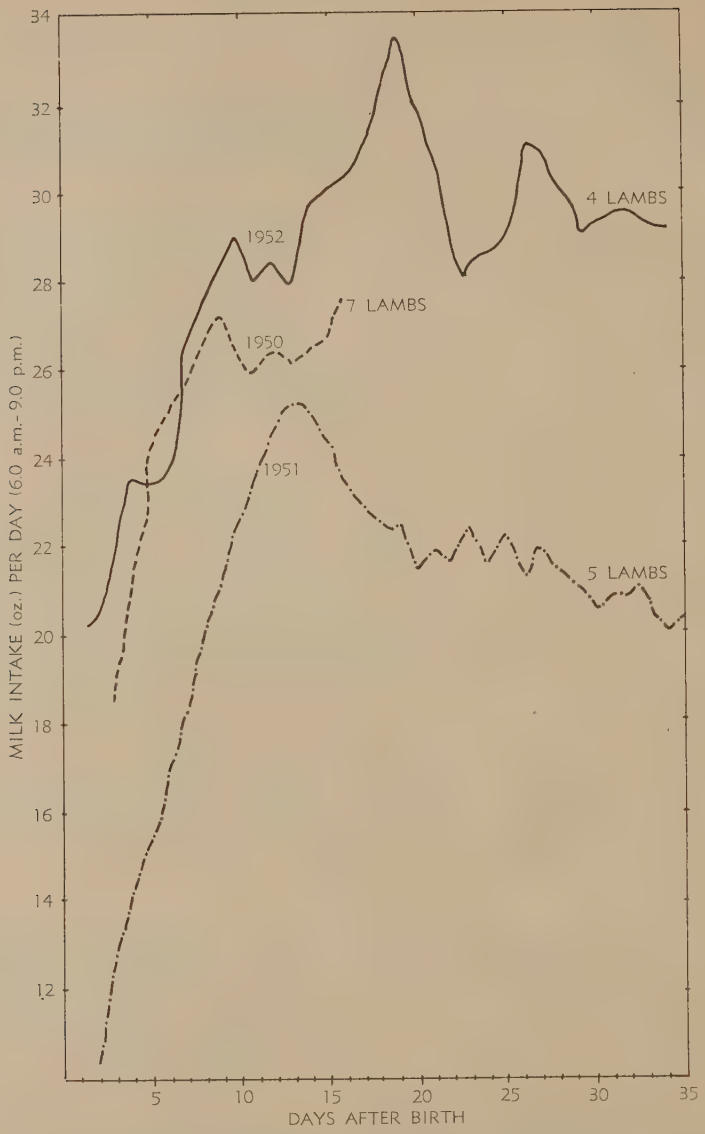

Fig. 1.—Mean daily milk intake of lambs during the first few weeks in 1950, 1951 and 1952. The results have been smoothed by the use of 3-day moving averages, i.e. the means of each consecutive 3 days.

(d) Effects of Different Nutritional Regimens After Lambing

Changes in the mean body-weight of the ewes in each group subjected to different nutritional regimens in the experiment conducted in 1952 are shown in Figure 2. The difference between the two groups that enjoyed a high plane of nutrition at the end of the experiment and those on a low plane is highly significant ($P<0{\cdot}001$).

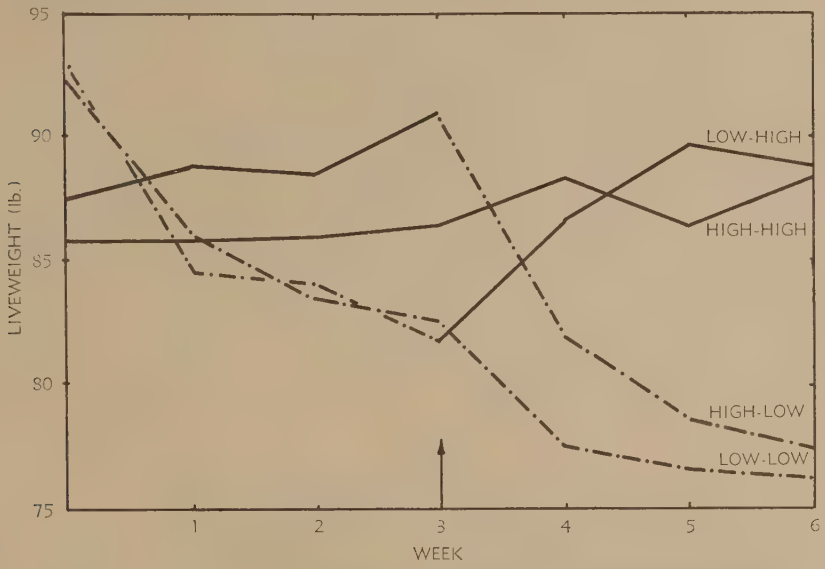

Fig. 2.—Mean weekly liveweights of ewes subjected to different nutritional treatments.

Mean measured daily milk intakes of each group of lambs for each period of the experiment are shown in Table 3, and the daily intakes are shown in Figure 3.

TABLE 3

MEAN MEASURED DAILY INTAKE OF THE 6 SINGLE LAMBS BORN TO EACH GROUP OF EWES SUBJECTED TO DIFFERENT PLANES OF NUTRITION—1952

Group : Nutritional Regimen	Daily Milk Intake (oz) (period 6.0 a.m.—9.0 p.m.)		
	Day 3 to 22	Day 23 to 42	Whole Period
High–High	24·8	22·3	23·5
High–Low	22·8	14·7	18·7
Low–High	19·1	21·4	20·2
Low–Low	19·4	14·6	17·0

Whole period : High-High greater than High-Low ($P<0{\cdot}05$)
High-High greater than Low-Low ($P<0{\cdot}01$)
First 20 days : Highs greater than Lows ($P<0{\cdot}01$)
Second 20 days : Highs greater than Lows ($P<0{\cdot}001$)

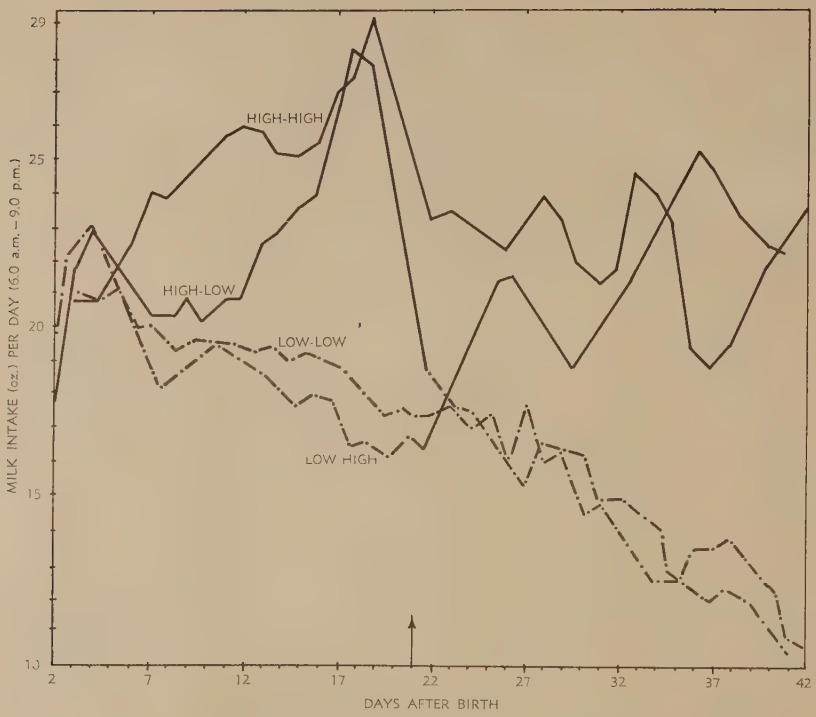

Fig. 3.—Mean daily milk intake of lambs whose mothers were subjected to different nutritional treatments. The results have been smoothed by the use of 3-day moving averages, i.e. the means of each consecutive 3 days.

In both 20-day periods the two groups of ewes receiving at that time the higher level of feeding yielded significantly more milk than those on the lower level of feeding. In neither period was there any significant difference between the two groups receiving the same treatment. Over the 40-day period the milk

TABLE 4

MEAN DAILY WEIGHT GAIN OF 6 LAMBS IN EACH GROUP WHOSE MOTHERS WERE SUBJECTED TO DIFFERENT PLANES OF NUTRITION—1952

Group	Daily Gain (oz)		
	1st 20 days	2nd 20 days	Whole Period
High–High	7·9	5·7	6·8
High–Low	7·7	2·9	5·3
Low–High	6·4	6·9	5·7
Low–Low	6·5	3·3	4·9

Whole period : High-High and Low-High greater than High-Low and Low-Low—($P < 0.001$)
High-Low greater than Low-Low ($P < 0.01$)

intake of the lambs of the High-High group exceeded that of the High-Low group ($P<0{\cdot}05$) and of the Low-Low group ($P<0{\cdot}01$).

The mean daily gains of the lambs in each group whose mothers were subjected to different planes of nutrition for each period and the whole of the experiment are shown in Table 4, which shows that the lambs from the High-High group made significantly greater gains than those in the remaining groups.

IV. DISCUSSION

The curves in Figures 1 and 3 reveal the large variation that occurred in daily milk intake. This raises doubts about the validity of the results that might be obtained under field conditions in the semi-arid tropics from the methods used by workers (Bonsma 1939; Barnicoat, Logan, and Grant 1949*a*, 1949*b*; Davies 1958; Owen 1957; Pierce 1934, 1936; Thomson and Thomson 1953; and Wallace 1948), who computed total milk production from measured milk intakes on selected days during lactation. On the other hand, high correlations were noted at the Trangie Agricultural Experiment Farm in New South Wales (Philpotts 1954) between 1-day tests and the weekly averages during the first and second weeks. The correlation between measured intakes separated by 24 hr was $+0{\cdot}86$, and between yields for 12 and 16 hr with 24 hr were $+0{\cdot}93$ and $+0{\cdot}95$ respectively.

The differences between milk intakes in 1950, 1951 and 1952 shown in Figure 1 are in keeping with the finding (Wallace 1948) that the plane of nutrition enjoyed by the ewes prior to lambing influenced milk production. However, a rapid increase in measured milk intake by Merino lambs during the first two or three weeks of life has not been noted by other workers (Bonsma 1939; Davies 1958), nor has the effect of incomplete emptying of the udder during the first few days been assessed in relation to milk production during the remainder of lactation.

The significantly lower intakes during the hottest parts of the day, when ambient air temperatures rose above 100°F, suggest that milk secretion may be decreased in an effort to conserve body fluids. Similarly, the negligible gains in liveweight achieved by the lambs during the day despite substantial milk intakes may reflect rapid evaporation of fluid necessary to maintain stable body temperatures; evaporation may be as high as 1 oz/hr when ambient air temperatures rise to 104°F (Alexander and Brook 1960). The loss of weight between 6.0 a.m. and 9.0 a.m. may be explained by the passing of urine and faeces following night feeding.

The differences between the milk production of the groups maintained on "High-High" and "Low-Low" nutritional planes in 1952 may reflect those that could well occur under the different grazing conditions that prevail from year to year in pastoral areas. In addition, the rapidity of the changes in milk production

that followed changes in the ration may not exaggerate the type of situation that can also occur in the Queensland environment. Extremely hot weather, or light falls of rain followed by cold weather, can damage much of the forage carried over from the summer growing periods, which constitutes the main source of food available to the sheep. As a result, the plane of nutrition can fall rapidly. Similarly, the plane of nutrition can rise suddenly if effective rains fall during lambing. The results presented in Figure 3 indicate that when this occurs Merino ewes may increase their milk production quickly and this was reflected in increased weight gains of the lambs (Table 4). The results also indicate that given adequate nutrition Merino ewes may still be producing considerable volumes of milk six weeks after parturition, but the milk production of ewes that are inadequately fed during the whole or the later part of lactation is rapidly reduced, and it also seems likely that the duration of lactation may be shortened.

Significant correlations have been noted by a number of workers between daily liveweight gain of lambs and the milk production of their mothers. In view of the results reported here and the daily weight gain of between 0·29 lb/day and 0·51 lb/day previously noted in Queensland (Moule 1954) it is suggested that given adequate good forage Merino ewes can milk well. However, under pastoral conditions high air temperatures and inadequate nutrition may contribute to lowered milk production of Merino ewes.

V. ACKNOWLEDGEMENTS

We are indebted to Mr. A. W. Beattie (Biometrician in the Queensland Department of Agriculture and Stock), who undertook the statistical analysis, and to the Australian Mercantile Land and Finance Company Ltd., which made sheep and facilities available. This work was financed under a grant from the Wool Research Trust Fund.

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EXPERIMENTAL *LEPTOSPIRA POMONA* INFECTION OF BOARS, INCLUDING STUDIES ON TRANSMISSION OF INFECTION BY COITUS

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SUMMARY

Four boars inoculated intramuscularly with *L. pomona* showed agglutinins and excreted leptospirae in the urine.

No clinical evidence of infection was seen.

Leptospiruria first occurred at 25 days in one boar, at 28 days in two and at 31 days in one. It was intermittent in all four animals, extending over periods of 16 to 21 days.

At slaughter, nine weeks after infection, the kidneys of all four boars showed greyish-white lesions of variable size, shape and distribution. The histological picture of the lesions was that of a focal interstitial nephritis. No abnormality was seen in the liver or testes.

Two of the boars were each mated during leptospiruria with three non-infected sows. None of the sows developed leptospiruria or showed antibodies against *L. pomona*.

I. INTRODUCTION

Experiments done at this Institute have shown that *Leptospira pomona* is a cause of abortion and neonatal mortality in swine (Ryley and Simmons 1954*a*, 1954*b*) while *Leptospira hyos*, another leptospiral serotype often present in pigs in Queensland, has failed to show such properties (Tammemagi and Simmons 1956, 1958). To our knowledge, no experimental work has been done specifically on *L. pomona* infection in boars.

This paper describes observations made on four boars experimentally infected with *L. pomona*, and data on the subsequent mating of two of these boars during leptospiruria, each with three uninfected sows.

II. METHODS

The four Large White and Wessex Saddleback cross boars (Nos. 461, 462, 463 and 466) used in the experiment were all nine months of age and were members of a litter from one sow in the Institute herd. Of the six sows mated

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to the infected boars, five (Nos. 425, 426, 427, 429 and 437) were gilts between 15 and 16 months of age, and one (sow 403), 24 months old, had had a litter some 8 months earlier. Four other sows, (Nos. 371, 400, 405 and 412), 20 to 24 months old, were mated to an uninfected boar and kept as controls. Of these, No. 412 was a gilt; sows 400 and 405 had farrowed once, and sow 371 twice, previously.

All animals were housed in separate concrete pens. Blood samples taken on several occasions prior to the commencement of the experiment did not contain antibodies for *Brucella suis, L. pomona* or *L. hyos*.

The four boars were inoculated into the gluteal muscles with 1·0 ml of a culture of *L. pomona* strain E.1377 previously used by Ryley and Simmons (1954) in their experimental work on leptospirosis in swine. The culture was obtained by sowing heart blood from a 21st guinea pig passage into Schuffner's medium and incubating for seven days.

Boars 462 and 463, while showing leptospiruria, were selected for serving three sows each. Boar 462 was mated to sows 425, 426 and 429, and boar 463 to sows 403, 427 and 437. When the infected boar was taken to the sow's pen, precautions were taken to minimize contact and so prevent the infection being transmitted by any route other than coitus. The sow was restrained with a rope around the upper jaw.

Immediately after service was completed, the boar was removed from the pen and the sow's skin and external genitalia washed and scrubbed with 2 per cent. lysol. Semen which dropped from the vulva immediately after service was removed from the floor, which was then liberally scrubbed with 2 per cent. lysol before the sow was released. Some sows continued to pass lumps of coagulated semen intermittently up to six hours after service. This material was not removed.

An attempt was made to arrange matings so that they occurred on days when the boars showed leptospiruria. Table 3 shows that this arrangement was successful in the mating of five of the six sows. Sow 429 was mated on the day when the boar's urine was negative for leptospirae, although the organisms were seen on the day prior to and on the day after mating. Each sow except 403 was mated only once to the selected boar; sow 403 returned to heat three weeks after the first mating and was mated again. During the first mating the boar's urine was positive for leptospirae, but at the second mating, which took place on two consecutive days, 15 days had elapsed since the boar had shown leptospiruria.

All boars and sows were examined daily and their rectal temperatures recorded twice daily. All dead piglets were necropsied and examined bacteriologically by the technique described by Ryley and Simmons (1954*b*).

Urine samples were collected daily from all boars for 63 days following inoculation and from the exposed sows for 42 days after service. The urine samples from sows were obtained by disturbing the sows about one hour after the morning feed and collecting the required sample into a sterile jar as they urinated. Collection from boars was done by restraining the animals in specially designed individual crates until they passed urine on to a tray, from which it drained through a funnel into a jar placed underneath. Urine samples were examined as described by Ryley and Simmons (1954*b*). No urine samples were collected from the control sows.

Blood samples were collected from the boars weekly for the first three weeks after exposure to *L. pomona* and later at intervals of two weeks. Samples from the sows of both exposed and control groups were collected every two weeks. The sera were kept at −25°C until the end of the experiment. All sera were then tested for agglutinating antibodies to *L. pomona,* on the same day and using the same batch of antigen. After incubation of the serum-antigen mixtures for 1·5 hr in a moist atmosphere at 37°C, the degree of agglutination was read under darkground illumination, using a magnification of 80.

Sixty-three days after exposure to infection, the boars were killed and the livers, kidneys and genitalia, including the accessory glands, were examined macroscopically. The testes and epididymides were weighed.

For histopathological examination, liver and kidney blocks were fixed in 10 per cent. neutral buffered formalin (Lillie 1948), and blocks of testis and epididymis in Bouin's solution. Tissue blocks were embedded in paraffin, cut at 7 microns and stained with haematoxylin and eosin. For identifying leptospirae, liver and kidney sections were stained by the technique of Warthin and Starry (Lillie 1948).

III. RESULTS

(a) Boars

(1) Clinical Observations

No ill-health was observed throughout the experiment in boars 462 and 463. Boar 461 had a watery diarrhoea and slight inappetence on the 14th and 15th days post-inoculation, and boar 466 showed slight inappetence on the 35th and 36th days after inoculation, i.e. on the 4th and 5th day after the commencement of leptospiruria.

Rectal temperatures throughout the experiment were within the normal range, the highest temperatures recorded being 103·2°F in boar 461, 103·1°F in boar 462 and 102·9°F in boars 463 and 466. These figures were comparable with those recorded during the 10 to 15 days' pre-exposure period.

(2) Urine Examination

Results of urine examination are shown in Table 1. Leptospiruria in all four boars was intermittent (Figure 1). On one day, morning and evening samples were collected from three boars. In boars 461 and 463, both the samples were positive for leptospirae, but in 461 the afternoon sample was negative although leptospirae were seen in the morning sample.

TABLE 1

DETAILS OF LEPTOSPIRURIA

Boar No.	Leptospiruria (days after inoculation)		Duration (days)	Number of Positive Daily Samples
	Commenced	Ceased		
461	28	45	18	12
462	28	48	21	13
463	25	42	18	13
466	31	46	16	6

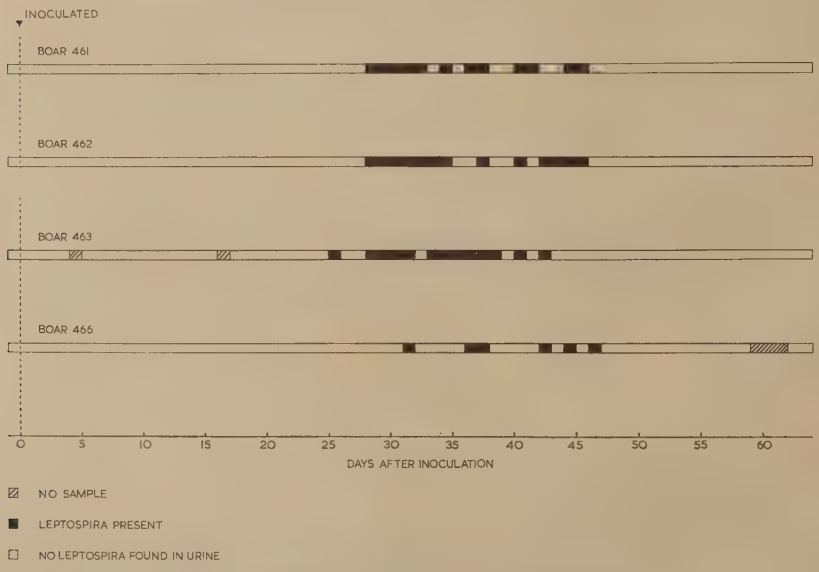

Fig. 1.—Examination of urine for leptospirae.

The number of leptospirae in the urine was never high and they were often dead and misshapen.

(3) Serology

The sera from the 10 sows showed no agglutinins to *L. pomona* throughout the whole trial.

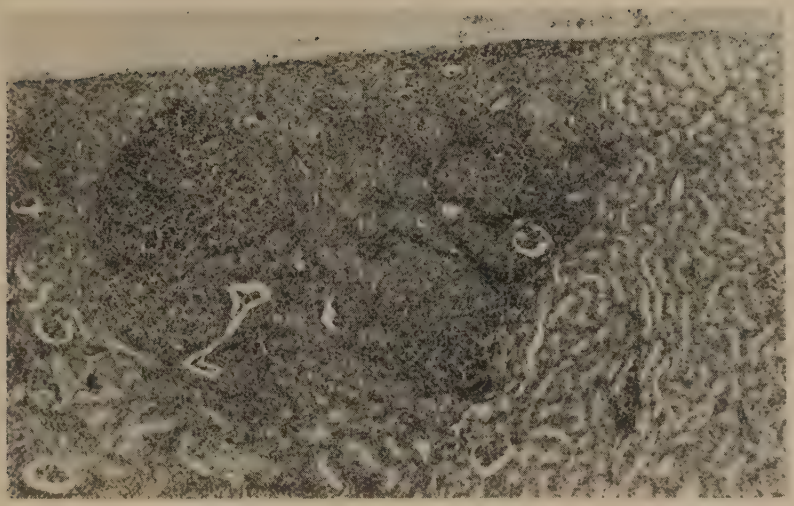

Fig. 2.—Kidney. X 50. Haematoxylin and eosin. Note the destruction of the subscapsular parenchyma. (X 16¾, enlarged X 3. Wratten filters 15 and 58.)

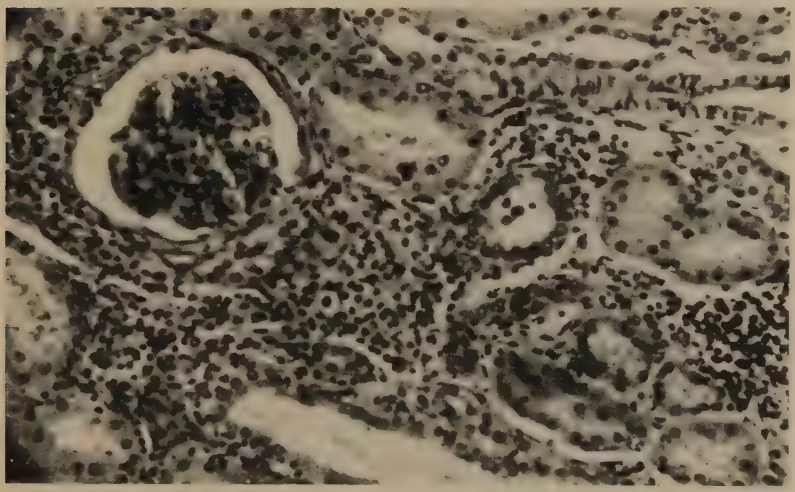

Fig. 3.—Kidney. X 225. Haematoxylin and eosin. An early focus of intertubular and periglomerular mononuclear infiltration. (X 75, enlarged X3. Wratten filters 15 and 58.)

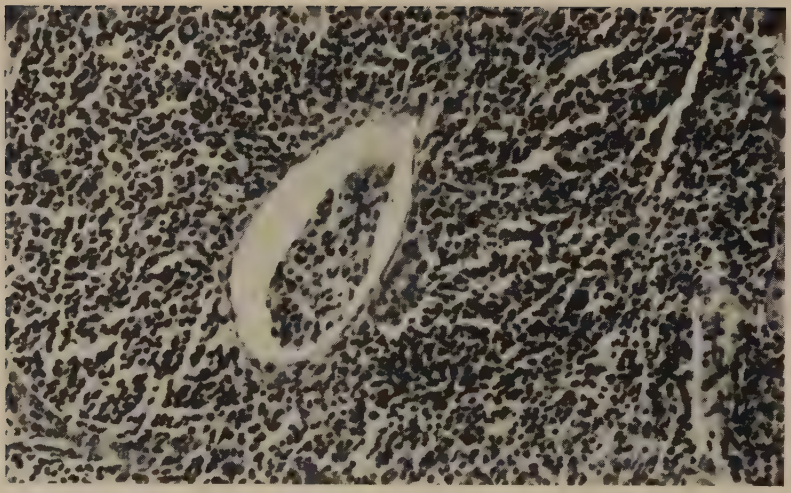

Fig. 4.—Kidney. X 225. Haematoxylin and eosin. Massive mononuclear infiltration causing complete destruction of the tubules. An atrophic glomerulus lies surrounded by infiltrating mononuclear cells which have completely destroyed the renal tubules. (X 75, enlarged X 3. Wratten filters 15 and 58.)

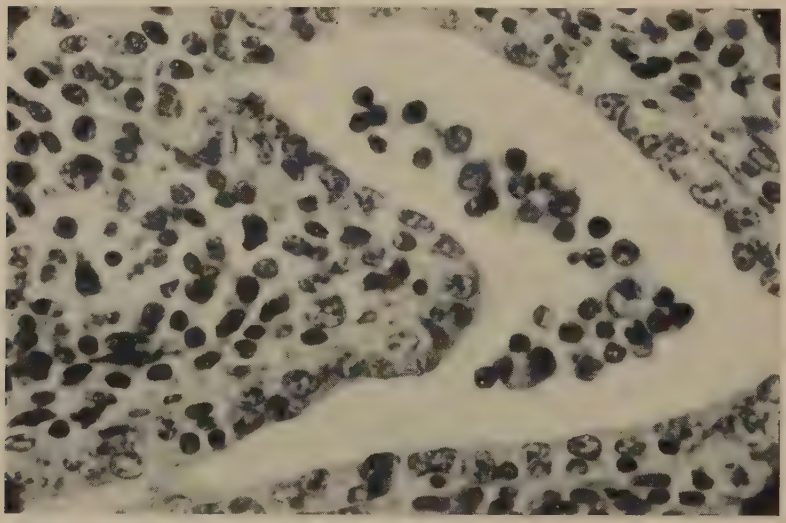

Fig. 5.—Kidney. X 750. Haematoxylin and eosin. Macrophages and lymphoid cells border an isolated tubule which contains a cellular cast. (X 250, enlarged X 3. Wratten filters 15 and 58.)

The results of the agglutination tests on the infected boars' sera are shown in Table 2. The maximum titres ranged from 1/1,000 to 1/3,000. The peak was reached within 14 days after infection in boars 461 and 462, but only after the 49th day in the other two boars. The secondary rise in the antibody titre in boars 461 and 462 between the 49th and 63rd days is not considered significant, since it represents an increase of only one dilution in the titration and is within the expected experimental error of this type of test.

TABLE 2

RESULTS OF AGGLUTINATION TESTS ON SERA FROM INFECTED BOARS

Boar No.	Days After Inoculation						
	0	7	14	21	35	49	63
461 ..	0	300+	3000	3000	1000	1000	3000
462 ..	0	30	1000	300	300	300	1000
463 ..	0	30	300	1000	1000	3000	1000
466 ..	0	30	300	300	300	1000	1000

Key : + Reciprocals of titres. Read at approximately 50% agglutination.
0 No agglutinins.

NOTE.—Leptospiruria commenced in boars 461 and 462 on the 28th, in boar 463 on the 25th, and in boar 466 on the 31st day after inoculation.

(4) Pathology

No gross lesions were seen in the livers or genitalia from the boars. The weights of the testes, including epididymides, were 325/320 g (left/right) in boar 461, 365/350 in boar 462, 325/325 in boar 463 and 410/395 in boar 466.

The kidneys in all four boars showed numerous greyish-white circumscribed lesions about 2 mm in diameter and a number of smaller, less well-defined foci scattered subcapsularly or situated more deeply in the cortex. The lesions were particularly numerous in boar 463.

(5) Histopathology

Histopathological examination showed significant changes only in the kidneys. These changes were those of focal interstitial nephritis. Non-purulent inflammatory foci of varying size were scattered through the renal cortices from the subcapsular area to the cortico-medullary junctions (Figure 2.) The medullae were free of lesions. The majority of the inflammatory cells were either lymphoid cells or macrophages, but eosinophils, neutrophils and plasma cells were seen occasionally. In early lesions, inflammatory cells were invariably found perivascularly about the interlobular arteries, but foci were also often seen intertubularly (Figure 3) and sometimes periglomerularly. As the lesions advanced in size, tubules were destroyed and glomeruli became atrophic (Figure 4). In the large foci, the normal kidney architecture was lost (Figure 2), but an occasional shrunken glomerulus or tubule could be detected in a mass of

mononuclear cells (Figure 4). Some of the surviving tubules contained syncytial masses with several tubule cell type nuclei. An occasional tubule in a mass of mononuclear cells contained cellular casts (Figure 5). No leptospirae were detected in any of the liver and kidney sections examined.

(b) Sows

None of the six sows exposed to the infection developed leptospiruria as judged by examination of urine samples. Serum samples from the exposed and control sows throughout the trial were negative for the presence of *L. pomona* antibodies.

The live piglets born to the exposed and control sows were bled periodically but none of them developed antibodies against *L. pomona.*

The gestation periods in the sows (Table 3) ranged from 114 to 117 days, compared with 113 to 116 days in the control sows.

A total of 44 piglets, eight of which were dead at birth, was born to the six sows. The size of the litters varied from 5 to 10 (Table 3). In the control group, 38 piglets (one dead) were born to the four sows, with litter sizes varying from 5 to 13.

(c) Piglets

Of the eight dead piglets in the exposed group, four belonged to a litter of five from sow 425. Their weights ranged from 2·0 to 3·0 lb. In all four, there was excess serosanguineous fluid in the pleural and peritoneal cavities. One of them showed a yellow fatty liver, but otherwise no significant abnormality was seen in these piglets.

The dead piglet in the litter from sow 403, weighing 1·9 lb, was covered with foetal membranes and was decomposed. Eight of the nine litter mates had body-weights from 3·0 to 4·5 lb. The other weighed only 2·2 lb, and it was, a few hours later, crushed by the sow.

The weight of the dead piglet, 4·0 lb, from sow 427 was comparable with that of the live litter mates (3·5 to 4·5 lb). Necropsy showed no gross abnormality in the piglet.

The remaining two dead piglets, 2·1 and 2·6 lb body-weight, were in litter from sow 437. No gross abnormality was seen in either piglet. The live piglets ranged in weight from 4·0 to 4·5 lb.

The only dead piglet in the control group was born to gilt 412. It was decomposed and the body weight, 1·9 lb, was the lowest for this litter, which ranged from 2·9 to 3·8 lb. No significant changes were revealed at the necropsy.

TABLE 3

BREEDING DATA OF EXPOSED AND CONTROL SOWS

Sow No.	Mated to Boar No.	Leptospira Present in the Boar's Urine on Day of Service	Date of Service	Date of Parturition	Gestation Period (days)	Number of Piglets Born	
						Total	Born Dead
Exposed Sows—							
425	462	+	8/ix/59	31/xii/59	114	5	4
426	462	+	31/viii/59	26/xii/59	117	5	0
429	462	—	7/ix/59	30/xii/59	114	10	0
427	463	+	3/ix/59	27/xii/59	115	8	1
437	463	+	31/viii/59	25/xii/59	116	7	2
403	463	+	4/ix/59				
			Remated		115	9	1
		—	23–24/ix/59	16/i/60			
Control sows—							
371	Herd boar ..	..	15/ix/59	7/i/60	113	9	0
400	Herd boar ..	..	14/v/59	4/ix/59	113	13	0
405	Herd boar ..	..	11/v/59	2/ix/59	114	11	0
412	Herd boar ..	..	11/v/59	25/ix/59	116	5	1

No Brucellae or Leptospirae were isolated from any of the dead piglets by culture and guinea pig inoculation, and darkground examination of the pleural and peritoneal fluids gave negative findings in all instances.

A wide range of contaminants, such as alpha haemolytic streptococci, micrococci, Proteus and a Bacillus, were cultured from all the dead piglets, but coliforms in addition were constantly recovered from the various tissues, including the brain and foetal membranes from each of the four dead piglets of sow 425.

IV. DISCUSSION

The experiment has shown that boars can readily be infected with *L. pomona* by the intramuscular route. The four boars subjected to infection developed leptospiruria and showed specific antibodies in their blood.

The leptospiruria in the boars in this experiment commenced somewhat later, but was more uniform in duration than that experienced at this Institute by Ryley and Simmons (1954*b*) in their experimental infection of sows with *L. pomona*. Although the same strain of *L. pomona* was used in both experiments, they recorded leptospiruria for periods of 7 to 83 days in sows after a comparatively short incubation period of 9 to 19 days, as against an incubation period of 25 to 31 days' and 16 to 21 days' duration in the present trial. Of interest was the intermittent nature of leptospiruria in the boars in the present trial as compared with a more continuous shedding of leptospirae in sows in the experiment of Ryley and Simmons (1954*b*). This phenomenon may be due to some difference in the virulence of the leptospiral culture rather than the sex of the animals, as a similar observation was made by Tammemagi and Simmons (1956, 1958) in two trials with *L. hyos*. However, the apparent intermittency could be a reflection of the limitation of the darkfield examination in detecting small numbers of leptospirae, or simply due to concentration differences on passage of urine in boars. That this may be so is supported by the result that a morning urine sample was positive in one instance when the evening collection from the same boar was negative.

None of the boars showed febrile reactions such as were observed by Burnstein and Baker (1954) and Ferguson and Powers (1956) in sows infected experimentally with *L. pomona*.

The macroscopical, as well as the microscopical, kidney lesions in the boars were similar to those observed in pigs by Burnstein and Baker (1954), Langham, Morse, and Morter (1958), and Sleight, Langham, and Morter (1960). Our description corresponds well with that given by Pallaske (1960) and Nieberle-Cohrs (1952) for focal interstitial nephritis. Pallaske (1960) makes the point that interstitial nephritis in the pig tends to be focal rather than diffuse as seen in man and occasionally in the calf.

Infection has been produced by pen contact from infected pen mates (Schmidt and Giovanella 1947; Morter and Morse 1956; Burnstein and Baker 1954), by subcutaneous infection (Burnstein and Baker 1954), by installation of culture into the conjunctival sac or nostrils (Schmidt and Giovanella 1947; Burnstein and Baker 1954; Ferguson and Powers 1956) and by deposition of leptospirae into the vagina (Ferguson and Powers 1956). Though the intravaginal route as reported by Ferguson and Powers was successful in setting up leptospirosis in the sows, our work produced no evidence that this will occur naturally even though the boars may be showing leptospirauria at time of service.

The failure to produce infection in the sows may have been due to the small number of leptospirae transferred at service, since the number of organisms shed by the boars in the urine was small and therefore the likely contamination of genitalia must be correspondingly so.

Our experiments did not indicate that the fertility of the boars had become impaired as a result of the *L. pomona* infection.

The incidence of still-born piglets, one or two per litter, is not of any great significance, as we have seen this occur in our breeding stock, mainly in litters consisting of 10 or more piglets per litter. The birth of four dead piglets to sow 425 is considered to be probably due to *Escherichia coli* infection. This organism was recovered from a wide range of piglets' organs, including brain and foetal membranes. Generally, coliforms are common post-mortem invaders, but as the sow subsequently showed a persistent bacteruria, and *E. coli* was repeatedly isolated from the urine, it is possible that the sow was affected with a chronic infection of the urinary tract which may have extended to the genital tract, so causing prenatal death of piglets.

V. ACKNOWLEDGEMENTS

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HEAT PROCESSING OF CREAM THROUGH VACUUM DEODORIZATION EQUIPMENT

1. A COMPARISON OF TANDEM AND TRIPLE VACREATION PROCESSING OF CREAM

By W. D. Mitchell, B.Agr.Sc. *

SUMMARY

Tandem and triple vacreation of cream were compared from three aspects, viz. (a) removal of volatile off-flavours, (b) efficiency of bacterial destruction, and (c) loss of butterfat in buttermilk after churning of the cream. The cream used was choice grade, but included three categories, "sound", "fair" and "borderline", within this grade.

The triple system showed an advantage over the tandem system in the removal of volatile off-flavours from "borderline" choice cream, but there were no differences in the quality of butter from "sound" choice and "fair" choice creams.

Both tandem and triple vacreation resulted in satisfactory destruction of bacteria in cream, but there were fewer survivors in the triple vacreated cream.

The butterfat losses in buttermilk derived from the churning of the cream were similar for both treatments.

I. INTRODUCTION

Vacuum deodorization associated with heat treatment has been employed successfully for the processing of cream for buttermaking in several dairying countries for the past three decades. In recent years, McDowall (1955, 1956, 1957, 1959), Scott (1954, 1955, 1956) and Dixon (1957) have examined the theoretical aspects of steam distillation of taints from cream.

The high numbers and varied flora of bacteria in farm-separated, acid cream supplied to Queensland factories, which normally receive the cream four times weekly in summer and thrice weekly in winter, result in much cream containing appreciable quantities of tainting substances of bacteriological origin. In the production of a "choice" grade butter at factories, the high quality cream is selected by sensory grading and subjected to intensive processing to reduce the concentration of taints sufficiently in the treated cream to ensure the production of butter of the desired quality. Lower quality creams are selected, intensively processed and made into first and second grade butters. The relatively low amount of choice grade butter manufactured in Queensland, which fluctuates yearly between 30 and 45 per cent. of total graded manufacture, indicates the severity of the off-flavours in cream produced in the subtropical environment.

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The trend to more intensive forms of cream processing in Queensland factories was reported by Mitchell (1957). His survey revealed an increase in recent years in the number of tandem and triple "Vacreators" and "Cream Treatment Units" and a reduction in the number of flash pasteurizers, volatilizers and solo "Vacreators" used in factories. Observations in factories where triple "Vacreators" are installed have shown that the tandem unit is employed for treating lower acid cream during the months of low production.

As the trend in processing indicated an attempt to improve butter quality through the application of intensive forms of heating and deodorization of cream, experiments were conducted under commercial conditions to compare tandem and triple vacreation treatment of cream.

Bacteriological examinations of cream and butter, organoleptic gradings on fresh and stored butter, peroxide values and copper and iron analyses of butter, and butterfat losses in buttermilk were undertaken.

II. METHODS

The following procedures were adopted in the experimental and analytical work.

Cream Processing Conditions.—As a wide variety of processing conditions is practicable with vacreation treatment of cream, treatments were standardized to conform with normal factory practices. The conditions aimed for in this investigation are listed in Table 1. In each instance, legs of the standard M-type unit were employed for processing.

TABLE 1

PROCESSING CONDITIONS FOR TANDEM AND TRIPLE VACREATION OF CREAM

Processing Conditions	Tandem	Triple
Cream flow (g.p.h.)	800	1,000
Pasteurization temperature (°F), Leg 1	..	200
Pasteurization temperature (°F), Leg 2	208	210
Vacuum conditions (in.), Leg 1	..	12
Vacuum conditions (in.), Leg 2	13	15
Vacuum conditions (in.), Leg 3	29	29
Water flow per condenser (g.p.h.)	2,500	2,500
Condenser water temperature rise (°F), Condenser 1	..	40
Condenser water temperature rise (°F), Condenser 2	50	60
Condenser water temperature rise (°F), Condenser 3	20	20
Treatment intensity (approx.)*	220	300
Total lb steam/gal cream†	2·6	3·4

* Treatment intensity is equivalent to the quantity of heat (water flow (g.p.h.) x temperature rise (°F)) discharged through the water condensers per gal of cream treated.

† Total steam consumption was estimated from temperature increase in condenser water and cream.

A residual acidity in the pasteurized cream of 0·04 to 0·08 per cent. was the objective during "neutralization" of cream.

Manufacturing conditions and composition of the butter were maintained as similar as possible for comparative churnings to minimize the influence of these factors on butter quality.

Cream Quality.—Raw cream was senses graded by two qualified graders and segregated to provide three distinct categories of choice grade cream designated "sound", "fair" and "borderline" choice. This was done to demonstrate the effect of intensive processing on the removal of off-flavours from creams having varying concentrations of taints.

As a general classification, the initial acidities of the respective categories of choice cream were 0·18 to 0·25 per cent. for sound, 0·26 to 0·35 per cent. for fair, and 0·36 to 0·45 per cent. for borderline.

The main characteristics of the creams selected were:—

(*a*) Sound choice—a clean, nutty flavour, together with a slight acid taste, free from traces of curd.

(*b*) Fair choice—free from strong off-flavours, but with a moderate clean, lactic acid content, or very slight stalish taste due to the age of the cream.

(*c*) Borderline choice—slightly unclean, slightly over-ripe flavour, or cream with trace of cheesy, bitter or stalish off-flavours; slight feed flavours were present in some creams; this cream was characterized by a distinct acid taste.

Every endeavour was made to eliminate from experimental batches creams containing weed taints, but this was found difficult with low-acid fresh cream supplies.

To ensure identical cream quality for paired comparisons, half of each batch of raw neutralized cream was treated through the tandem unit, after which processing was stopped and the machine converted to a triple unit immediately and the remaining portion of the cream treated.

Bacteriological Examinations.—Samples of raw and processed cream were examined for bacteriological content by the milk agar method described by Muller and Nichols (1950) for butter samples. Single plate counts were done on single samples. Because of difficulties in maintaining accurate incubation temperatures, which fluctuated in the range of 28±3°F under field conditions, only a limited number of samples was examined.

The bacteriological content of fresh and stored butter was determined with single plate counts on duplicate samples by the methods specified for the Butter Improvement Service (Muller and Nichols 1950).

Chemical Examinations.—The moisture and salt contents of butter samples were determined by the Kohman (1919) method.

The pH of butter serum was determined by the glass electrode and quinhydrone electrode techniques.

The peroxide value of fresh and stored butter was determined by the ferric thiocyanate method of Loftus Hills and Thiel (1946), with chloroform-methanol solvent and a photoelectric colorimeter.

To ensure that butter quality was not influenced by metallic contamination, samples were analysed for copper and iron content by the wet ashing method of McDowell (1947).

Butterfat Losses.—Total fat lost in buttermilk was estimated by the Udy formula reported by McDowall and McDowell (1949) as suitable for washed butter. Butterfat content of cream to be churned was determined on a 9 g gravimetric sample and the fat content of the subsequent buttermilk by the modified normal butyl alcohol Babcock method (A.O.A.C.).

Butter Grading.—A 56 lb box of bulk butter from each churning was graded fresh and after storage for 6 months at 5-10°F. In addition, a 1 lb pat, double-wrapped in parchment, was examined after storage at 45–55°F for one month. Grading was performed by the State dairy produce grader and butter was scored to the nearest half point.

III. RESULTS

(a) Cream Processing Conditions

As trials were conducted during normal commercial factory operations it was not possible to guarantee complete compliance with listed processing conditions. Variations occurred in the rate of cream flow, flows of 750–850 g.p.h. and 950–1,050 g.p.h. occurring with tandem and triple treatments respectively. This fluctuation resulted in a corresponding variation of the order of 5–10 per cent. in treatment intensity and steam consumption per gallon of cream.

The total churnings prepared were six paired comparisons of sound choice, six paired comparisons of fair choice, and seven paired comparisons of borderline choice quality cream. This involved using 19,000 gal of cream.

(b) Bacteriological Quality of Cream

The results of the bacteriological examination of samples of raw and pasteurized cream are listed in Table 2.

TABLE 2

BACTERIOLOGICAL QUALITY OF RAW AND PROCESSED CREAM
(Colonies per millilitre)

Cream Quality	No. of Samples								
	Raw Cream (,000,000)			Tandem Treatment (,000)			Triple Treatment (,000)		
	<100	100–300	>300	<30	30–100	>100	<30	30–100	>100
Sound choice ..	..	4	6	4	5	1	8	1	1
Fair choice ..	..	..	4	2	..	2	2	2	..
Borderline choice	..	..	6	3	3	..	5	1	..
Totals ..	..	4	16	9	8	3	15	4	1

As a consequence of the limiting testing procedures described, an accurate total bacterial count of cream was not obtained for all samples examined. Results are therefore grouped in ranges. With identical creams it was found that triple processing with its double-heat treatment gave a greater bacterial kill than occurred in the single-heat treatment of tandem vacreation.

(c) Chemical Results

A summary of the chemical analyses of cream and butter from comparative churnings is listed in Table 3.

TABLE 3

MEAN CHEMICAL COMPOSITION OF CREAM AND BUTTER FOR TANDEM AND TRIPLE VACREATION

Chemical Property	Sound Choice		Fair Choice		Borderline Choice	
	Tandem	Triple	Tandem	Triple	Tandem	Triple
Residual cream acidity (%)	0·06*	0·06*	0·07†	0·07†	0·06‡	0·07‡
Butter serum pH (quinhydrone)	7·5*	7·5*	7·4†	7·3†	7·4‡	7·3‡
Butter serum pH (glass electrode)	7·5*	7·5*	7·4†	7·3†	7·4‡	7·3‡
Peroxide value (fresh) ..	0·03	0·03	0·03	0·03	0·03	0·03
Peroxide value (1 mth) ..	0·05	0·05	0·04	0·06	0·05	0·06
Peroxide value (6 mth) ..	0·12	0·16	0·18	0·21	0·24	0·37
Copper (p.p.m.)	0·2*	0·2*	0·2†	0·2†	0·2‡	0·2‡
Iron (p.p.m.)	1·1*	0·8*	1·0†	1·0†	1·0‡	1·2‡
Moisture (%)	15·6	15·8	15·7	15·7	15·7	15·7
Salt (%)	1·1	1·1	1·2	1·2	1·1	1·1

* Mean of 5 of 6 total churnings.
† Mean of 4 of 6 total churnings.
‡ Mean of 5 of 7 total churnings.

These results show a close similarity between treatments, with the exception of peroxide values for butter stored for six months, where values from triple treatment were higher.

Moisture distribution in all butters as determined by the Muller (1952) technique was satisfactory.

(d) Bacteriological Quality of Butter

The bacteriological quality of experimental butters is summarized in Tables 4, 5 and 6.

Coliform and yeast and mould counts in fresh and stored butters were rather high. As total count determinations on cream indicated adequate heat treatment, the presence of these micro-organisms indicated post-pasteurization contamination. The physical condition of the internal surfaces of the wooden butter churn barrels used in the manufacture of the trial churnings was somewhat open along the stave joins and the contamination probably occurred from this source despite intensive cleaning procedures.

No significant change in bacteriological condition between fresh and 4-week-old samples was evident in any of the three grade categories for both tandem and triple treatment.

Between fresh and 6-month storage samples there was significant decline in the population of yeast and mould organisms for sound choice triple treatment. A similar significant decline was found in the coliform and the yeast and mould contents for fair choice triple treatment, and in the total count, coliform and yeast and mould organisms with triple processing of borderline choice cream.

With tandem vacreation treatment there was a significant decline between fresh and 6-month storage butters in the coliform and yeast and mould counts for all classes of cream. In addition, a significant reduction in the total count was obtained for tandem treatment of fair choice cream.

With the exception of three counts—viz. the total count and casein digester content of 6-month storage butter from sound choice cream, and the yeast and mould population in the 4-week borderline choice sample—there was no significant difference in the bacteriological content of butters prepared from the tandem and triple treatments of the same cream.

(e) Butterfat Losses

The fat lost in the buttermilk was estimated as the total fat lost from the cream churned. Results for the two treatments and three categories of cream are depicted graphically in Figure 1. The average increases in total fat loss for triple treatment of + 0·11 per cent., + 0·04 per cent., and + 0·06 per cent. for sound, fair and borderline choice creams, respectively, as compared with the tandem treatment creams, are considered to be of no practical significance.

TABLE 4

BACTERIOLOGICAL QUALITY OF FRESH BUTTERS

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean)		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	119 ± 15	132 ± 33	7 ± 1	10 ± 2	15 ± 2	18 ± 5	272 ± 61	300 ± 35
Fair choice ..	200 ± 28	196 ± 21	11 ± 2	9 ± 1	49 ± 9	71 ± 18	518 ± 109	373 ± 66
Borderline choice	152 ± 32	204 ± 38	8 ± 1	9 ± 1	38 ± 14	73 ± 22	353 ± 65	376 ± 63

TABLE 5

BACTERIOLOGICAL QUALITY OF BUTTER STORED FOR SIX MONTHS AT 5–10°F

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean)		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	43 ± 8	160 ± 46	5 ± 1	9 ± 3	0	16 ± 11	50 ± 13	63 ± 16
Fair choice ..	107 ± 27	179 ± 34	10 ± 1	10 ± 1	3 ± 1	5 ± 2	116 ± 52	155 ± 48
Borderline choice	103 ± 33	96 ± 23	10 ± 1	8 ± 1	2 ± 1	3 ± 1	131 ± 53	115 ± 46

TABLE 6

BACTERIOLOGICAL QUALITY OF BUTTER STORED FOR FOUR WEEKS AT 45–55°F

Cream Quality	Bacteriological Quality (colonies/ml)							
	Total Count (Mean) (,000)		Casein Digesters (Mean) (,000)		Coliforms (Mean		Yeasts and Moulds (Mean)	
	Tandem	Triple	Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	129 ± 29	158 ± 33	9 ± 2	9 ± 2	12 ± 3	10 ± 2	403 ± 110	506 ± 115
Fair choice ..	203 ± 39	196 ± 30	8 ± 1	8 ± 2	51 ± 14	35 ± 7	346 ± 62	358 ± 114
Borderline choice	121 ± 21	148 ± 31	10 ± 1	9 ± 2	17 ± 3	16 ± 5	416 ± 81	214 ± 53

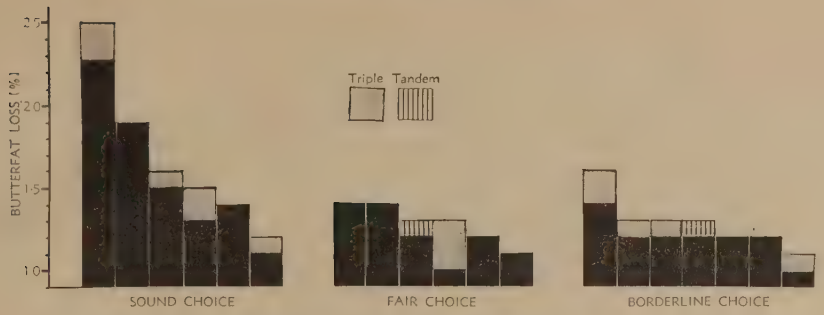

Fig. 1.—Histograms showing butterfat losses in creams of various qualities submitted to triple and tandem vacreation. (Common butterfat loss represented by solid area.)

The two high losses for sound choice creams for both treatments were from creams with residual pH levels slightly higher than other churnings (e.g. 7·6-7·8, in contrast with 7·4) and from creams with butterfat contents 2-3 per cent. lower than normal. These factors probably accounted for the higher losses.

(f) Butter Grading

Grading results for all churnings, together with a general comment on defects, are summarized in Table 7.

As the amount of butter scored true-to-grade is a factory criterion for assessing the suitability of cream grading and processing techniques, grading results for this investigation were reported also in this manner.

It was found that there was little difference in the mean points score and the number of true-to-grade churnings with butter from sound and fair choice cream after tandem and triple treatments. This similarity was evident for both fresh and stored butters.

A better quality butter, both fresh and stored, was manufactured from borderline choice cream processed in the triple unit than from similar cream treated in the tandem unit. While the mean points score of fresh samples for both treatments was similar, the one true-to-grade churning for tandem treatment in contrast to the four true-to-grade churnings for triple treatment indicated that this cream processed by the tandem treatment yielded a butter slightly lower than choice quality.

Although every endeavour was made to eliminate weed taints from raw cream supplies, two churnings of sound choice and one churning each of fair and borderline choice contained weed off-flavours. This incidence of taint in the small number of trial churnings prepared in each cream class influenced the comparative nature of the trial treatments both in the number of true-to-grade churnings and in the mean points score.

TABLE 7

BUTTER GRADING RESULTS OF CREAMS PROCESSED BY TANDEM AND TRIPLE VACREATION

Cream Quality	Storage Conditions	Total Churnings	Butter Quality					
			True to Grade		Mean Points Score		Grading Comments	
			Tandem	Triple	Tandem	Triple	Tandem	Triple
Sound choice ..	Fresh	6	3	4	92·6	92·8	Trace to very slight weed (2)	Trace to very slight weed (2)
Fair choice ..	..	6	5	5	93·0	92·8	Very slight weed (1)	Very slight weed (1)
Borderline choice	..	7	1	4	92·4	92·6	Very slight to slight unclean Very slight stale Very slight weed (1)	Very slight unclean Very slight stale Very slight weed (1)
Sound choice ..	6 months at 5–10°F	6	2	1	92·1	92·3	Very slight weed (1) Very slight unclean Slight stale	Very slight weed (1) Very slight unclean Very slight stale
Fair choice ..	..	6	1	1	92·1	92·0	Very slight to slight unclean Very slight to slight stale	Very slight to slight unclean Slight stale
Borderline choice	..	7	1	1	91·4	92·1	Very slight to slight unclean Very slight to slight stale Trace fermented Very slight weed (1)	Very slight to slight unclean Slight stale
Sound choice ..	4 weeks at 45–55°F	6	1	2	92·1	91·9	Very slight weed (1) Very slight stale Very slight unclean	Very slight weed (1) Very slight to slight stale
Fair choice ..	..	6	3	3	92·3	92·4	Slight unclean Slight stale in 3 churns Very slight weed (1)	Very slight unclean Very slight stale in 3 churns Very slight weed (1)
Borderline choice	..	7	0	3	91·2	92·0	Very slight to slight unclean Very slight to slight stale Very slight weed (1)	Very slight to slight stale Very slight weed (1)

IV. DISCUSSION

(a) Pasteurization Efficiency

The results of the bacteriological quality of pasteurized cream in this investigation support the findings of Muller (1951). He reported satisfactory bactericidal efficiency when temperatures in excess of 200°F were used for processing cream in a solo "Vacreator". The lower counts obtained in cream after processing in the tandem unit (a combination of a solo heating unit and a deodorization cooling section) at a temperature of 208°F indicated that these temperatures are adequate for pasteurization of cream for buttermaking. Pin-point colonies on the agar plates characterized the surviving organisms, which were considered to be inert thermoduric bacteria.

The greater bactericidal effect of the triple vacreation demonstrated in this trial could be a consequence of the increased time-temperature conditions of treatment. However, as the counts obtained on cream treated in the tandem unit were considered satisfactory, no practical advantage in pasteurization can be claimed for the more intensive treatment.

(b) Deodorization Efficiency

Efficiency of taint removal in multiple-vessel "Vacreator" deodorization equipment has been expressed by Scott (1954) in terms of the following formula.

$$\text{Percentage taint remaining} = 100 \times \frac{1}{1 + \frac{mv}{L}}$$

where m = equilibrium constant
v = outflow of steam (lb/hr)
L = inflow of liquid (lb/hr)

He has further proposed (Scott 1959) equilibrium constants of $m = 15$-20 for creams in which taints are highly volatile (sound choice), $m = 10$ where taints are of average volatility (fair choice), and $m = 5$ for creams characterized by taints of low volatility which are often associated with acid cream or poor quality cream.

Applying these theoretical considerations to the conditions of treatment in this investigation, the following residual taint concentrations were calculated.

Processing Treatment	Cream Quality	Percentage of Initial Taint Remaining
Tandem	Sound choice ..	15
	Fair choice	24
	Borderline choice ..	43
Triple	Sound choice ..	7
	Fair choice	13
	Borderline choice ..	30

Organoleptic grading results on fresh and stored butters manufactured from sound and fair choice creams revealed no difference in quality for tandem and triple treatment. With the exception of three weed-tainted consignments, eight of the nine remaining fresh churnings of sound and fair choice cream scored true-to-grade. Riddett *et al.* (1939) reported similar findings on New Zealand butters, where with finest quality cream the more intensive deodorization obtainable with tandem vacreation in comparison with flash-pasteurization made no significant difference in the resultant butter quality. This suggests that where weed flavour is absent, carry-over of taint contamination into processed creams of concentrations up to 25-30 per cent. of the initial level will pass undetected by senses grading in fresh butters. As the partial distribution coefficients between butterfat and serum of the various tainting substances are unknown, the quantity present in the subsequent butter could not be calculated. With borderline choice creams, triple vacreation ensured a greater number of churnings of butter scoring choice rating. Because of the small number (7) of comparative churnings available, this advantage has been examined in further trials and results will be reported in a subsequent paper. With tandem treatment, four of six degraded churnings scored 92½ points, indicating that the estimated level of taint contamination retained, viz. 40 per cent., was a threshold concentration for down-grading.

Butter deterioration in storage was generally greater with lower quality creams. The overall loss of points score of 0·5 to 1·0 points with butter from borderline choice creams was of a slightly lower order than that reported by Crittall (1957) of 1·5 to 2·0 points in investigations with choice creams of similar quality.

The influence of the relatively high bacterial content on the quality of stored butter is unknown. However, all butter exhibited a satisfactory dispersion of moisture when manufactured and in this condition the bacterial population should not impair the flavour of butter to any marked extent.

Along with increased steam consumption with triple vacreation of cream, it was possible to treat the cream at a much faster rate and maintain butter quality. This is an economic consideration where large total quantities of cream must be processed daily.

(c) Butterfat Losses

Dolby (1957) reported that breaking-up of fat globules occurs in those parts of the "Vacreator" where a mixture of steam and cream attains a high velocity. Levels of fat lost in the buttermilk for the two treatments of the same cream in this trial were similar. However, a comparison of lb of steam injected per lb of cream in the pasteurization legs of the two treatments revealed a close similarity (Table 8) and could explain the identical level of losses with the two treatments. The conditions of turbulence obtained in Leg 1 and Leg 2, respectively, of the triple unit were of a similar magnitude to those applied in the single pasteurization leg of the tandem unit.

TABLE 8

QUANTITY OF "WASH" STEAM USED IN TANDEM AND TRIPLE VACREATION

Treatment	lb "wash" steam/lb cream			
	Pasteurization Leg 1	Pasteurization Leg 2	Cooling Leg 3	Total
Tandem	..	·16	·06	·22
Triple	·10	·15	·05	·30

A similar quantity of flash steam was generated in the cooling section of both machines.

V. ACKNOWLEDGEMENTS

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Technical Notes

A NOTE ON SWEET POTATO WEEVIL IN CENTRAL QUEENSLAND

The sweet potato weevil, *Cylas formicarius elegantulus* (Sum.), occasionally causes severe damage to crops of sweet potatoes (*Ipomoea batatas* (L.) Lamk.) in Central Queensland.

During 1955-1960, 8 randomized block trials, with a plot size of 40 plants, were carried out to investigate the status of the pest and the possibility of economic control by chemical means. Planting was between August and March, with cuttings as the material in all except one trial where small tubers were used.

In two trials the cuttings were dipped in DDT emulsion (0·4 per cent. active), BHC dispersible powder (0·1) and emulsifiable preparations of dieldrin (0·2), aldrin (0·2), endrin (0·2), toxaphene (0·4), chlordane (0·4) and parathion (0·05). Planting was during hot dry weather, and severe burning occurred despite moist soil conditions and immediate post-planting irrigation.

In other trials, sprays of the insecticides at half the strengths given above were applied up to five times at fortnightly intervals. In two of these, DDT (5 lb active per acre), dieldrin (5), BHC (2·5) and aldrin (2·5) dusts were used as preplant soil dressings either alone or in combination with spray treatments.

In one trial, large numbers of weevils were active in crown runners prior to the first spray.

Tubers were harvested approximately six months after planting date, except in one trial which was planted in August and not dug until the following August: this is a common practice on dairy farms, where the top growth is used for autumn and early winter feed and the tubers are turned up as required for grazing during late winter.

Weevil infestations in tubers were virtually non-existent at harvest in both treated and check plots of all trials. There were no significant yield differences among treatments, or between treatments and checks.

Results from these trials and field observations suggest that damage in runners is not important unless severe growth checks occur. Appreciable tuber infestation may be encountered only when tubers are exposed and this can be prevented in most seasons by deep planting of tubers and hilling before runner growth becomes too prolific.

In Central Queensland, severe weevil damage to sweet potatoes can be expected only when crops are grown continually in adjacent areas with little regard for field hygiene, and during droughts. Potential yields under these conditions are so low that expenditure on insecticides is not warranted.

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SEED-HARVESTING ANT CONTROL IN THE CLONCURRY DISTRICT

Seed-harvesting ants of the genus *Iridomyrmex* represent a major problem in establishment of pastures of buffel grass (*Cenchrus ciliaris* L.) in many areas of Queensland. Associated problems concern soil pH and water, and nutrients available to the seed at germination.

Methods of seed treatment for pest control have been established in many countries, as have pelleting methods associated with improvement of moisture retention and nutrition of germinating seed. A trial was designed therefore to test the effectiveness of seed treatment, including pelleting, for control of seed-harvesting ants in the Cloncurry area. Basic treatments compared were sowing seed on ploughed land against unploughed land, pelleting with lime or basic superphosphate against no pelleting, and inclusion of lindane or aldrin in the seed treatment against no insecticide treatment.

The site selected was on "Granada" station, near Cloncurry, where facilities and assistance were provided by The Australian Estates Company Ltd. and the Station Manager (Mr. R. Scandrett).

An analysis of a composite soil sample from the area gave:

pH		7·1
Available P_2O_5		400 p.p.m.
Replaceable K		0·9 m-equiv. per 100 g
Morgan Test	NO_3 Nitrogen	Low
	NH_3 Nitrogen	Low
Texture		Light-brown sandy loam

The soils concerned were the deep, well-drained Dugald River alluvials, apparently suitable for buffel grass growth. There was no major slope in the trial area but occasional lower lying areas were indicated by local dominance by *Dichanthium* sp. The vegetation was an open savannah formation in which the major tree species were silver box (*Eucalyptus pruinosa* Schau.), bloodwood (*E. terminalis* F. Muell.), ghost gum (*E. papuana* F. Muell.), *Bauhinia cunninghamii* Benth., and mimosa bush (*Acacia farnesiana* Willd.). Ground species were dominated by *Aristida latifolia* Domin, with *Heteropogon contortus* (L.) Beauv. and *Chrysopogon fallax* S. T. Blake dominating small areas. Other grasses and herbs found in the area included *Dichanthium* sp., *Leptochloa digitata* (R.Br.) Domin, *Enneapogon avenaceus* (Lindl.) C. E. Hubbard, *Perotis rara* R.Br., *Tragus australianus* S. T. Blake, *Panicum majusculum* F. Muell. ex Benth., *Sporobolus* spp., *Iseilema* sp., and *Malvastrum spicatum* (L.) A. Gray. Isolated colonies of local buffel grass were present also.

The trial area measured 15 chains by 12 chains. Colonization strips 6 ft wide were pegged across the area at 1-chain intervals. A plot contained 3 chains of colonization strip, and the middle chain was used as datum area. Ploughing treatments were carried out immediately before planting with a chisel plough equipped with sweeps.

The seeding rate was 0·93 oz (approximately 9,200 seeds) per chain of colonization strip. For pelleting treatments, lime or basic superphosphate was applied to seed wetted with 0·25 per cent. detergent solution to give seed : fertilizer weight ratios of 1 : 6–7 and 1 : 5 respectively. Insecticide treatments with aldrin (10 per cent. active) or lindane (10 per cent. gamma isomer) as dispersible powders were applied directly to the seed or premixed with pelleting material at the rate of 1 part of insecticide to 40 parts of seed by weight.

Seed (Cloncurry strain, 31 per cent. germination) was hand-sown on January 29, 1960, and relevant rainfall records are given in Table 1.

TABLE 1

RAINFALL DURING PROGRESS OF TRIAL

Month	Dates and Amounts of Rain (in.)									
December, 1959	Date ..	18								
	Rainfall	1·69								
January, 1960 ..	Date ..	10	11	12	13	25	26	27	28	29
	Rainfall	·25	·62	·68	·88	·71	·98	·15	·10	(Planting)
February, 1960 ..	Date ..	9	10	11	19	20	21	22	23	24
	Rainfall	·09	2·03	1·02	1·69	·11	·70	·02	·73	·11
March, 1960 ..	Date ..	17	18	28						
	Rainfall	·31	·16	(Assessment)						

At assessment, regrowth from old stools of *Chrysopogon fallax, Heteropogon contortus,* and *Aristida latifolia* was common on ploughed plots, as were the native annuals *Perotis rara* and *Dactyloctenium radulans* (R.Br.) Beauv. Isolated plants of naturally occurring buffel grass were present in or near the plot. Results of the assessment are presented in Table 2.

Under the conditions of the trial, field establishment did not exceed 20 per cent. of viable seed. Though apparently low, such establishment will provide satisfactory buffel grass stands.

Concurrent with field work, germination tests on a different batch of seed were made in the laboratory and nursery, and results are given in Table 3. Laboratory germinations are means of 2 tests of 200 seeds each, and nursery germinations are means of 3 replications of 200 seeds per plot planted as a randomized block layout.

TABLE 2

SEEDLING ESTABLISHMENT OF BUFFEL GRASS PELLETED WITH BASIC SUPERPHOSPHATE OR LIME, AND ALDRIN OR LINDANE

Cultural Treatment	Pelleting Material	Insecticide	Buffel Grass Seedlings per Chain of Colonization Strip			
			Block 1	Block 2	Block 3	Mean
Unploughed	Nil	Nil	0	0	0	0
	Lime	Nil	8*	20*	0	—
	Basic superphosphate	Nil	0	0	0	0
	Nil	Aldrin	0	0	0	0
	Lime	Aldrin	1	1	0	1
	Basic superphosphate	Aldrin	4	28*	1	11
	Nil	Lindane	0	0	1	0
	Lime	Lindane	196*	0	0	—
	Basic superphosphate	Lindane	0	0	1	0
Ploughed	Nil	Nil	1	5*	5	—
	Lime	Nil	33*	38*	51	—
	Basic superphosphate	Nil	62	2	57	40
	Nil	Aldrin	276	166*	353	314
	Lime	Aldrin	814	729	203	582
	Basic superphosphate	Aldrin	404	74	35	171
	Nil	Lindane	6*	1	22*	—
	Lime	Lindane	680	488	209	459
	Basic superphosphate	Lindane	509*	534	411	472

* Naturally occurring buffel grass in or near the plot.

TABLE 3

LABORATORY AND NURSERY GERMINATION OF BUFFEL GRASS, CLONCURRY STRAIN

Pelleting Material	Insecticide	Laboratory Germination (%) (Tested 10 days after treatment)			Nursery Germination (%) (Planted 28 days after treatment ; counted 51 days after treatment)
		Water	KNO_3	Days	
Nil	Nil	56	57	21	61
Lime	Nil	0	0	21	21
Basic superphosphate	Nil	1	4	21	23
Nil	Aldrin	17	14	21	31
Lime	Aldrin	0	0	21	20
Basic superphosphate	Aldrin	1	3	17	33
Nil	Lindane	6	2	21	50
Lime	Lindane	0	0	21	18
Basic superphosphate	Lindane	4	2	21	23
Kaolin	Aldrin	1	1	21	47
Kaolin	Lindane	3	3	21	37

Germination of lindane-treated seed is abnormal under laboratory conditions and may be slower, but where such seed is planted in the field, establishment is affected less seriously. Aldrin does not cause visible abnormality.

In summary, primary establishment of buffel grass was satisfactory in treatments including ploughing and pelleting with inclusion of insecticide. As a standard control measure is desirable for both low and high available phosphate areas, a recommendation has been made that all buffel grass seed planted in areas in which seed-harvesting ants are active should be pelleted with basic superphosphate and lindane (Champ and Sillar 1961).

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EFFECT OF POLYETHYLENE CASE LINERS ON THE COOL STORAGE BEHAVIOUR OF GRANNY SMITH AND DELICIOUS APPLES

It has been demonstrated by a number of overseas workers that the cool storage of some varieties of apples is beneficially affected by the use of polyethylene case liners.

Ryall and Uota (1955) found that apples of the Yellow Newtown variety stored in 150-gauge polyethylene case liners at 40°F remained greener in colour and firmer in texture and developed less superficial scald than those stored at the same temperature in 100-gauge polyethylene case liners or without case liners. The work of Hardenburg (1956) over two seasons with eastern-grown Golden Delicious apples showed that sealed and non-sealed polyethylene case liners were very effective in preventing weight loss and shrivelling of this variety during storage at 31°F for six months. He also found that a disadvantage of the liners was an increased tendency of the fruit to scald when moved to 70°F following cool storage. His work indicated a slight gas storage effect, evidenced as a slower ripening rate, in the sealed polyethylene liners. Subsequent work by Hardenburg and Siegelman (1957) with five varieties of apples showed that the benefits of slower ripening and reduced scald were not obtained with non-sealed film liners, but confirmed earlier results with respect to the weight loss reduction obtained by these liners.

Smock and Blanpied (1956) reported that sealed polyethylene case liners produced undesirable side-effects, such as off-flavours and carbon dioxide injury, in the Cortland and Rhode Island Greening varieties. Further work by Smock and Blanpied (1958) with 11 varieties of apples showed that the use of sealed polyethylene case liners may or may not extend the storage life of apples. They found many difficulties presented themselves when sealed liners were used with un-precooled fruit that had not had prior fungicide treatments. Off-flavours were sometimes present, carbon dioxide injury occurred, decay was often increased and scald usually increased with unsealed liners and often increased with sealed liners. Hardenburg and Anderson (1959), working with five apple varieties, once again confirmed that sealed 150-gauge liners delayed ripening and reduced weight loss and shrivelling, but found that the liners did not give good commercial control of scald. Heavier gauge liners were not successful as they did not have an adequate gas permeability rate.

Padfield (1960) investigated the use of both waxed paper and polyethylene case liners with four varieties of apples and three varieties of pears. He found that with most of the tested varieties case liners reduced weight loss and wilt, polyethylene bags being the most effective. However, he did not recommend these bags for storage of New Zealand apples and pears, since while they sometimes reduced storage disorders they often increased disorders.

Experiments were carried out in Queensland by the authors during the 1957 and 1958 apple seasons with the Granny Smith variety, and during the 1958 season with the Delicious variety, to determine the effect of 150-gauge polyethylene case liners on the cool storage behaviour of Queensland grown apples.

Methods and Materials

In each of the three separate experiments the experimental design was the same. The fruit used was obtained from five different growers in the Granite Belt, surrounding Stanthorpe, and comprised six half-bushel cases from each grower, i.e. 30 half-bushel cases for each experiment. In each experiment three half-bushel cases from each grower were used as an untreated control. The remaining fruit was packed into three half-bushel cases lined with 150-gauge polyethylene case liners. Each liner was constructed as a large bag, and was so made that when packed there was an overlap of approximately 18 in. After packing the fruit into the liner the overlap was folded tightly and twisted a number of times before the case was lidded. Prior to packing, the Granny Smith apples were wrapped in oiled paper wraps containing 15 per cent. mineral oil in order to control superficial scald, and the Delicious apples were wrapped in sulphite paper wraps.

The picking dates of the fruit were:—

Granny Smith—April 25, 1957.
April 30, 1958.

Delicious—March 12, 1958.

After picking and packing, the fruit was railed to Brisbane and stored in the Hamilton Cool Stores at 34°F. Dates of removal of the fruit from the storage chamber were—

Granny Smith—November 28, 1957.
November 27, 1958.

Delicious—September 30, 1958.

After the fruit was removed from store it was held for seven days at normal atmospheric temperatures to simulate normal marketing delays, and then inspected for disorders. Five fruit were taken from each case and two measurements of firmness were made on each fruit with a Magness Penetrometer, using the $\frac{7}{16}$ in. plunger.

Results

Granny Smith.—From the results summarized in Table 1, it appears that the liners have a small effect in controlling storage disorders. Wide variation with respect to storage disorders was encountered among fruit from different

sources. Certain trends exist which show an apparent effect on scald incidence. The liners appeared to increase the presence of superficial scald; this effect is in accordance with both the American and the New Zealand results. They also seem to have an effect in reducing the incidence of late scald. They had no significant effect on the firmness of the fruit.

TABLE 1

GRANNY SMITH—PLASTIC LINER TRIAL

Percentages of Various Defects

Treatment	1957					
	Mould (%)	Superficial Scald (%)	Late Scald (%)	Soggy Breakdown (%)	Total Wastage (%)	Firmness (lb)
Control	4·6	0·4	20·9	9·6	33·8	12·1
Liners	3·8	7·9	0·3	4·9	15·7	12·9

Total wastage.—No significant differences, due to marked variation according to source of fruit. Effect of liners over all sources almost significant at 5% level.

Firmness.—No significant differences.

Mould, Superficial scald, Late scald and *Soggy breakdown.*—No analysis of variance carried out because of wide variation between source of fruit.

Treatment	1958					
	Mould (%)	Superficial Scald (%)	Late Scald (%)	Soggy Breakdown (%)	Total Wastage (%)	Firmness (lb)
Control	16·7	10·8	24·1	0·4	55·9	9·33
Liners	7·8	21·2	2·4	1·9	36·7	9·20

Total wastage.—Liners significantly less than no liners (5% level).

Superficial scald.—No significant differences.

Firmness.—No significant differences.

Mould, Late scald and *Soggy breakdown.*—No analysis of variance carried out because of wide variation between source of fruit.

Delicious.—The results are summarized in Table 2. Polyethylene case liners had no significant effect on the presence of storage disorders in this variety. There was a similar trend in the results to that found with the Granny Smith variety in that the liners apparently caused an increase in the incidence of superficial scald.

TABLE 2

DELICIOUS—PLASTIC LINER TRIAL 1958

Treatment	Mould (%)	Superficial Scald (%)	Soggy Breakdown (%)	Withered Fruit (%)	Total Wastage (%)	Firmness (lb)
Control	4·8	37·4	0·7	7·4	37·1	11·4
Liner	3·9	26·6	14·4	0	51·6	10·7

Total wastage.—No significant differences.

Superficial scald.—No significant differences.

Firmness.—No significant differences.

Mould, Soggy breakdown and Withered fruit.—No analysis of variance carried out.

Discussion

In the Granny Smith experiments there was no fruit showing any withering, but the general appearance of the fruit in the polyethylene liners was much better than that stored in cases without liners. Some withering of Delicious occurred in the cases without liners, but none was present when the fruit was enclosed in liners. The fresh appearance of the fruit in liners was most marked. The results generally are in agreement with those of overseas workers with respect to an increase in superficial scald with liners and the improvement in appearance with a reduction in withering. However, the advantages of the liners appear to be of such small magnitude that their use for Queensland apples does not warrant recommendation.

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A USEFUL SOIL SAMPLING TUBE

Various soil sampling devices have been used by the authors in soil moisture studies in the Mareeba-Dimbulah area of North Queensland. Samplers of the tube type have been found to offer certain advantages over the auger type, firstly because the depth from which the sample is obtained can be more accurately controlled with a tube, and secondly because samples can be obtained in close proximity to a growing plant, as no turning action is required.

This note describes a useful, inexpensive soil sampling tube which operates very satisfactorily on the soil types encountered.

The sampler is constructed from 16-gauge mild steel drawn tubing with an internal diameter of $1\frac{5}{8}$ in. The tubing is cut with pipe-cutters which leave the cutting tip with a slight inward taper. This taper disappears with use but is not essential for the satisfactory operation of the sampler. The cutting edge can be touched up as required. A collar 5-6 in. in length is welded to the top of the tube to form a driving head and to prevent burring. Two $\frac{1}{2}$ in. mild steel handles 6 in. long are welded to the collar and reinforced with steel plates. Depth intervals can be marked off by making a shallow cut with the pipe-cutters.

Two tubes which can be used to sample to a depth of 120 cm (4 ft) are illustrated in Figure 1, together with a standard Veihmeyer tube for comparison.

The sampler can be pushed in quite easily when the soil is approaching field capacity. As the soil dries out, a wooden mallet is used for driving the tube into the soil. With experience the operator can feel large rocks or roots and thus prevent damage to the cutting tip.

Little trouble has been experienced in extracting the tube. The sample cores readily even on dry sandy soils and the straight walls of the cylinder prevent core loss by suction, such as sometimes occurs on these soil types with the standard Veihmeyer tube.

It has been found that 10 cm (4 in.) is a convenient operating depth. A sample of this size fills a 4 oz pomade jar and provides 120-180 g of oven-dry soil. The authors consider that the sampler described gives a more representative sample than a Veihmeyer tube.

As with other tube samplers, there is always some contamination at the top of the sample, but this can be separated quite easily from the required sample.

Using this soil sampling tube, two men can extract 10 cm samples to a depth of 90 cm at six positions within an area of 30-40 sq. yd. in approximately 60 min. In a tobacco irrigation trial it is possible to sample a chain row at six positions to a depth of 60 cm in 10 cm increments in 30 min.

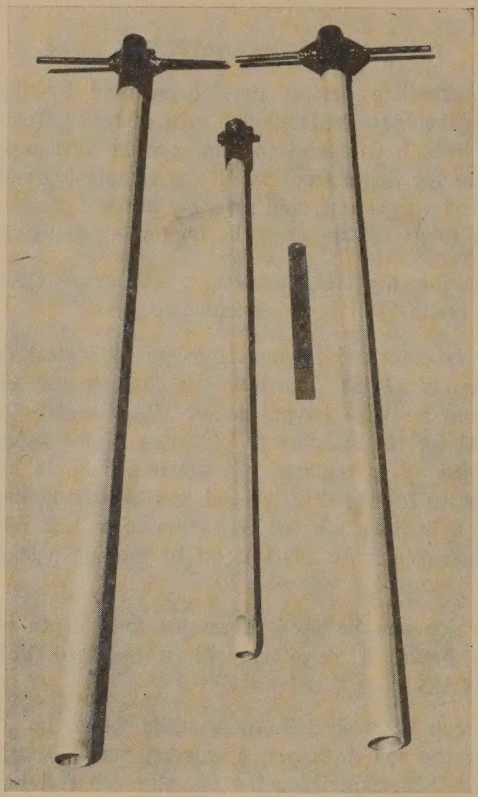

Fig. 1.—Soil sampling tubes of the type described and a standard Veihmeyer tube.

The tube has operated satisfactorily in soils covering the following range of mechanical analyses:

Coarse Sand %	Fine Sand %	Silt %	Clay %	Texture
8	51	12	29	clay loam
12	60	19	9	loam
31	60	5	4	loamy sand
78	19	2	1	sand

The sampler has been particularly useful in moisture studies on the light sandy soils of the Mareeba-Dimbulah area and should prove useful on similar soil types.

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CONTENTS

Heritable Variation in Nodulation of *Centrosema pubescens* Benth. By G. D. Bowen and Margaret M. Kennedy 161

Peach Brown Rot Investigations in Queensland. By K. N. Shea .. 171

Comparative Morphological Studies of *Heliothis* Species (Lepidoptera: Noctuidae) in Queensland. By T. H. Kirkpatrick 179

Queensland Distributions and Host Records for *Heliothis* Species (Lepidoptera: Noctuidae). By T. H. Kirkpatrick 195

Studies of Plant and Soil Nematodes. 4. *Tylenchulus obscurus* n.sp. (Nematoda: Tylenchulidae). By R. C. Colbran 203

Effect of Grazing Management on an Irrigated Pasture in South-eastern Queensland. By C. A. Schroder 209

Field Observations on the Daily Milk Intake of Merino Lambs in Semi-arid Tropical Queensland. By G. R. Moule and R. B. Young .. 221

Experimental *Leptospira pomona* Infection of Boars, Including Studies on Transmission of Infection by Coitus. By L. Tammemagi, C. G. Simmons, M. D. McGavin and C. G. Ludford 231

Heat Processing of Cream Through Vacuum Deodorization Equipment. 1. A Comparison of Tandem and Triple Vacreation Processing of Cream. By W. D. Mitchell 241

TECHNICAL NOTES

A Note on Sweet Potato Weevil in Central Queensland. By T. Passlow and P. D. Rossiter 255

Seed-harvesting Ant Control in the Cloncurry District. By B. R. Champ, D. I. Sillar and H. J. Lavery 257

Effect of Polyethylene Case Liners on the Cool Storage Behaviour of Granny Smith and Delicious Apples. By C. D. Stevenson and J. R. Blake 261

A Useful Soil Sampling Tube. By G. D. Keefer and D. K. Ward .. 267